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Cover: An Antenna-waving Wasp, *Tachysphex pechumani*, and its prey, *Melanoplus eurycerus*, photographed by Bob Jacksy, Oak Openings Preserve, Metroparks, Lucas County, Ohio, courtesy of Frank E. Kurczewski. See article on the biogeography of this species in southern Ontario pages 1-20.

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History of White Pine (*Pinus strobus*)/oak (*Quercus* spp.) Savanna in Southern Ontario, with Particular Reference to the Biogeography and Status of the Antenna-waving Wasp, *Tachysphex pechumani* (Hymenoptera: Sphecidae)*

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Kurczewski, Frank E. 2000. History of White Pine (*Pinus strobus*)/oak (*Quercus* spp.) savanna in southern Ontario, with particular reference to the biogeography and status of the Antenna-waving Wasp, *Tachysphex pechumani* (Hymenoptera: Sphecidae). Canadian Field-Naturalist 114(1): 1–20.

The entry of *Tachysphex pechumani* into southwestern Ontario, estimated at 8000 to 6500 yr B. P. (before the present), is linked to ameliorated climate, Great Lakes low water levels, exposed sandy shores and land bridges, and abundance of White Pine-graminoid-herb savanna. Its putative historical geographic distribution in the region is traced to late 18th and early 19th century oak/pine woodland; scrubby, bushy and burnt oak/pine vegetation; oak, oak-hickory and oak-pine plains; and White Pine-Red Pine plains. The current geographic distribution of the Antenna-waving Wasp, a rare insect on sandy soils in southwestern Ontario, is limited to three widely separated populations: (1) north of Lake Erie near Long Point; (2) southern shore of Lake Huron near Pinery Provincial Park; and (3) south of Georgian Bay on Canadian Forces Base Borden. Reforestation, fire suppression, excessive off-road motorized vehicular traffic, and insecticide use are threats to these populations.

Key Words: Antenna-waving Wasp, *Tachysphex pechumani*, White Pine/oak savanna, postglacial dispersal, southern Ontario.

Oak (*Quercus* spp.) savanna and pine (*Pinus* spp.) barrens are imperiled ecosystems in southern Ontario. Preserving and maintaining these two types of habitats should be a priority for conservation organizations. Much oak and pine-dominated forest, oak savanna, and pine barrens was removed from this region by logging and land clearance between 1800 and 1850. Agriculture and development eliminated most of the remaining oak-pine vegetation during the late 19th and early 20th centuries. Remnant oak savanna were often planted with coniferous trees to reduce sand erosion. Land modification in southern Ontario was devastatingly thorough due to extensive agricultural, urban and industrial expansion (Beazley and Nelson 1993; Maycock 1963).

Numerous endangered, rare and threatened species of plants and animals were lost from the region with the elimination or alteration of oak savanna and pine barrens. Among the Lepidoptera (butterflies and

moths), the Karner Blue Butterfly (*Lycaeides melissa samuelis* Nabokov), Frosted Elfin [*Incisalia irus* (Godart)] and Persius Duskywing [*Erynnis p. persius* (Scudder)] were extirpated from southern Ontario (Packer 1994; Sutherland and Bakowsky 1995). The fate of *Tachysphex pechumani* Krombein, the Antenna-waving Wasp (Figure 1), is also in jeopardy. This small, sand-nesting, grasshopper hunter is notable for its adult morphology, nesting behavior, ecology and seasonal and geographic distribution (Kurczewski 1987; Kurczewski and Elliott 1978). The species was listed by me as RARE in southwestern Ontario (Kurczewski 1998). Continued habitat destruction, vegetation succession due to fire suppression, reforestation or insecticide use could result eventually in the elimination of this insect from the region.

The purpose of this paper is to: (1) describe the early to mid-Holocene colonization potential for *T. pechumani* in southwestern Ontario using climatic, ecological and edaphic criteria; (2) relate the current geographic distribution of this species to late 18th and early 19th century oak/pine-dominated woodland, oak plains [savanna] and pine plains [barrens];

*Contribution number 1 of the Roosevelt Wildlife Station of the State University of New York College of Environmental Science and Forestry, Syracuse, New York.

Table 1. Summary of climatic, ecological and edaphic characteristics governing <i>Tachysphex pechumani</i> entry into southwestern Ontario.												
Age (Years Before Present)		10,000	9,000	8,000	7,000	6,000	5,000	4,000	3,000	2,000	1,000	0
Laurentide Ice Sheet		Gradual ice sheet retreat; diminishing impact on environment		Minimal impact **	Virtually no ice sheet impact on environment							
Climate		Cooler and moister			Warmer and drier					Gradually cooler and moister		
Precipitation/ evapotranspiration ratio*		Higher			Lower					Increasingly higher		
Convective thunderstorms/dry lightning strikes/natural fires		Decreased; low natural fire frequency			Increased; higher natural fire frequency					Decreased; reduced natural fire frequency		
Lakes Huron, Erie water levels		Generally low			Rising	High				Gradually lowering but still high		
Sandy shores, land bridges		Mainly wide			Narrowing	Narrow; inundated				Narrower and mainly inundated		
Forest conditions	Xeric soils	Jack & Red pine forest	White pine forest	White pine woodland & savanna						Oak savanna		
	Mesic soils											
Anthropogenic fires		Negligible		Limited	Mixed deciduous-coniferous forest							
Fossil insect record		Boreal species			Current insect fauna			Increased, especially purposeful and accidental fires				
<i>Tachysphex pechumani</i> habitation		Highly Unlikely	Unlikely			Increased population levels			Unknown population levels			
						Possible entry and colonization			Increased habitat destruction & fire suppression			

* Based on stable isotope, small interior lake level studies

** Gray areas represent transitional zones



FIGURE 1. Female of *Tachysphex pechumani* transporting paralyzed, immature *Melanoplus* sp. across sand, St. Williams Crown Forest Turkey Point Tract, Haldimand-Norfolk Regional Municipality, Ontario.

(3) determine the historical extent of this kind of vegetation in areas inhabited by the wasp using early land survey field note books and maps; (4) extrapolate the early Euro-Canadian settlement geographic distribution of this species from such information; (5) determine the present-day geographic range of *T. pechumani* in southern Ontario; and (6) discuss the conservation implications of its distribution.

Methods

The period of *T. pechumani* entry into and colonization of southwestern Ontario was estimated from fossil pollen and charcoal, plant macrofossils, fossil insects and other climate reconstruction information. Potential geographic distribution of the wasp during the early to mid-Holocene was extrapolated from these data and maps of ancient sand plains, paleowater-levels and paleoshorelines.

Copies of late 18th and early 19th century land survey field note books and maps were obtained through the Natural Heritage Information Centre, Peterborough, for the three areas inhabited by *T. pechumani* and several sandy sites without the wasp. Roads [wagon trails] or boundary lines with oak/pine-dominated woodland, burnt woods or plains and pertinent topographic features were delineated and converted into composite maps for each site. Historical geographic distribution of the wasp was assumed to coincide with late 18th and early 19th century oak/pine-dominated woodland, burnt woods and plains based upon the contemporary presence of the species in these habitats.

Measurements in chains and links along concession lines, lot lines and roads with oak/pine-dominated woodland, burnt woods and plains recorded in the surveyor's field note books were summed for each area. Chains and links were converted to meters and then to kilometers (100 links = 1 surveyor's chain; 1 surveyor's chain = 20.117 meters; 1000 meters = 1 kilometer).

Sixteen trips totalling 9400 km were made through sandy sections of southern Ontario (and Quebec) in 1995, 1996, 1997, 1998, and 1999 in an attempt to locate nesting aggregations of *T. pechumani*. Sites harboring the wasp were designated on a Ministry of Natural Resources map of southern Ontario. Existing vegetation including oak savanna and pine barrens was recorded for these sites. Several localities with sandy soil but no wasp history were also mapped and vegetation type recorded in an attempt to explain its absence.

Early to Mid-Holocene Wasp Distribution

Tachysphex pechumani probably entered southwestern Ontario between 8000 and 6500 years ago. At that time White Pine (*Pinus strobus*)-graminoid-herb-dominated savanna prevailed on the sandy and gravelly soils of the region (Hamilton 1994; Szeicz and MacDonald 1991) (Table 1). Although the Antenna-waving Wasp was not included, a fossil insect assemblage from Kitchener infers a somewhat earlier entry [8400-7900 yr B.P.] for this species into southwestern Ontario (Table 1) (Schwert et al. 1985). Some of these species and *T. pechumani* now

live south of Ontario in the Atlantic Coastal Plain. Whether *T. pechumani* moved northward with these insects or delayed entry until optimal habitat requirements were established is unknown. By 7500-7000 yr B. P. insect assemblages in the region were similar to those found in southern Ontario today, i.e., the modern fauna was established (Morgan 1987).

Tachysphex pechumani probably entered southwestern Ontario before the expansion of the deciduous forest which occurred between 7000 and 6000 yr B. P. (Table 1). Closed forest was detrimental to this species because it supplanted the sandy openings and savanna necessary for mating, hunting and nesting (Kurczewski 1998). Prior to that time, invasion by thermophilous deciduous species was suppressed by the cooler climatic conditions associated with the Laurentide Ice Sheet. This ice sheet did not disintegrate to a size where its effects on the environment were negligible until after 8000-7500 years ago. Then, summer warmth was established in the lower

Great Lakes Region facilitating the northward movement of the thermophilous species (Anderson and Lewis 1992). Aided by an ameliorated climate, Beech (*Fagus grandifolia*), Hemlock (*Tsuga canadensis*), Sugar Maple (*Acer saccharum*), elm (*Ulmus* spp.), oak (*Quercus* spp.), Basswood (*Tilia americana*), and White Ash (*Fraxinus americanus*) largely replaced White Pine (*Pinus strobus*) on the mesic soils of the region (Anderson 1995; Bernabo and T. Webb 1977; Karrow and Warner 1990; McAndrews 1981; Mott and Farley-Gill 1978; Schwert et al. 1985). White Pine remained abundant on the droughty soils of the Norfolk Sand Plain and other extensively sandy and gravelly areas in southwestern Ontario until the expansion of oak [probably White Oak (*Quercus alba*) and Black Oak (*Q. velutina*)] about 6500-6000 yr B. P. (Bennett 1987; Szeicz and MacDonald 1991) (Table 1).

Favorable conditions for the entry of *T. pechumani* into southwestern Ontario 8000 to 6500 yr

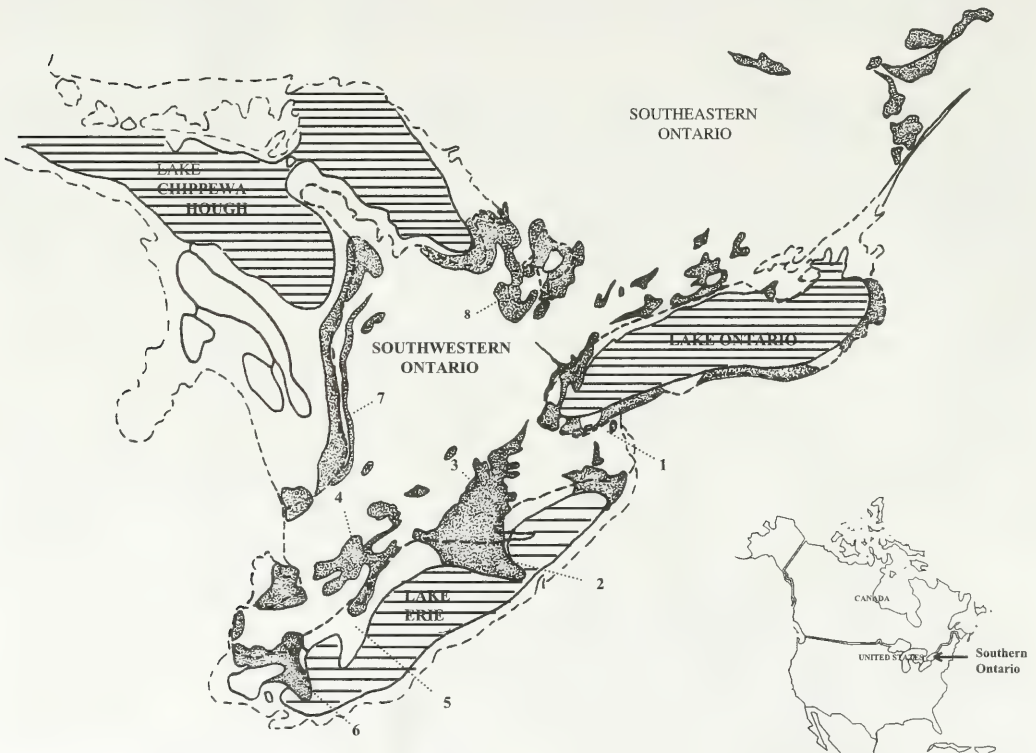


FIGURE 2. Southern Ontario showing low Great Lakes levels ca. 7800-7500 yr B. P. Paleoshorelines are indicated by dark solid lines; present-day shorelines are dashed lines. Ancestral sandy soils are darkly stippled. Physiographic areas are numbered as follows: (1) Niagara Peninsula; (2) Long Point; (3) Norfolk Sand Plain; (4) Caradoc Sand Plain; (5) Pointe Aux Pins; (6) Point Pelee; (7) Huron Fringe; (8) Camp Borden Sand Plain (Anderson and Lewis 1985, 1992; Chapman and Putnam 1984; Coakley 1976, 1989, 1992; Coakley and Karrow 1994; Karrow and Warner 1990; Lewis and Anderson 1989; Lewis et al. 1994; Rukavina and St. Jacques 1971, 1978; St. Jacques and Rukavina 1973; Thomas et al. 1972).

B. P. included warmer and drier climate, lowered Great Lakes water levels, reduced water tables, decreased effective soil moisture and retarded soil development on the sandy and gravelly soils (Anderson 1995; Karrow and Warner 1990; Szeicz and MacDonald 1991) (Table 1). Estimates for that period infer a mean July temperature 1-2°C warmer and annual amount of precipitation 10% less than present-day (Anderson 1995; McAndrews 1981; Schwert et al. 1985). Stable isotope studies indicate a warm and dry climate in the region by 7400 yr B. P. (Edwards and Fritz 1988). Reduced water levels for small inland lakes related to summer warmth and dryness and differential uplift are recorded for southern Ontario by 8000-6000 yr B. P. (Anderson 1995, 1997; Anderson et al. 1996; McAndrews 1984; Szeicz and MacDonald 1991; Yu and McAndrews 1994; Yu et al. 1996). [Zonal vegetation development related to climatic amelioration changed 1000 years later in southeastern than in southwestern Ontario (Karrow and Warner 1990)].

Lake levels in the Huron and Erie basins were low between 8000-5700 and 8000-5000 yr B. P., respectively, due partly to the diversion of Huron basin waters to the St. Lawrence River via an ancestral Ottawa River (Coakley 1989). Lake levels in the Huron basin reached a lowstand at 7800-7500 yr B. P. uncovering widespread, previously submerged sandy sediments (Anderson and Lewis 1992; Lewis

and Anderson 1989; Lewis et al. 1994). Widened sandy shores and land bridges exposed from reduced water levels and differential uplift between the Huron and Erie basins provided previously unavailable habitat for *T. pechumani* in southwestern Ontario (Figure 2; Table 1). This broadened sandy corridor was probably a dispersal thoroughfare and colonization stronghold for psammophilous plants and animals. Even after the Erie basin attained its highest water levels at about 4000 yr B. P. and then gradually lowered to present-day levels (Coakley 1989, 1992; Coakley and Lewis 1985; Lewis et al. 1994) (Table 1), more than 600 000 ha of sandy soils were available in southern Ontario for potential wasp habitation. There were 313 000 ha of predominantly sandy soils in the Norfolk Sand Plain alone (Chapman and Putnam 1984).

Oak savanna began replacing White Pine woodland and savanna on some of the sandy and gravelly soils in the Norfolk Sand Plain about 6000 yr B. P. (Szeicz and MacDonald 1991) (Table 1). An increased incidence of convective thunderstorms, dry lightning strikes and wildfires may have fueled this replacement. Southwestern Ontario was drought prone during the summers due to much precipitation falling on the elevated Dundalk Upland to the north (Brown et al. 1974) (Figure 3). Higher water levels in the Huron basin beginning at about 6000 yr. B. P.

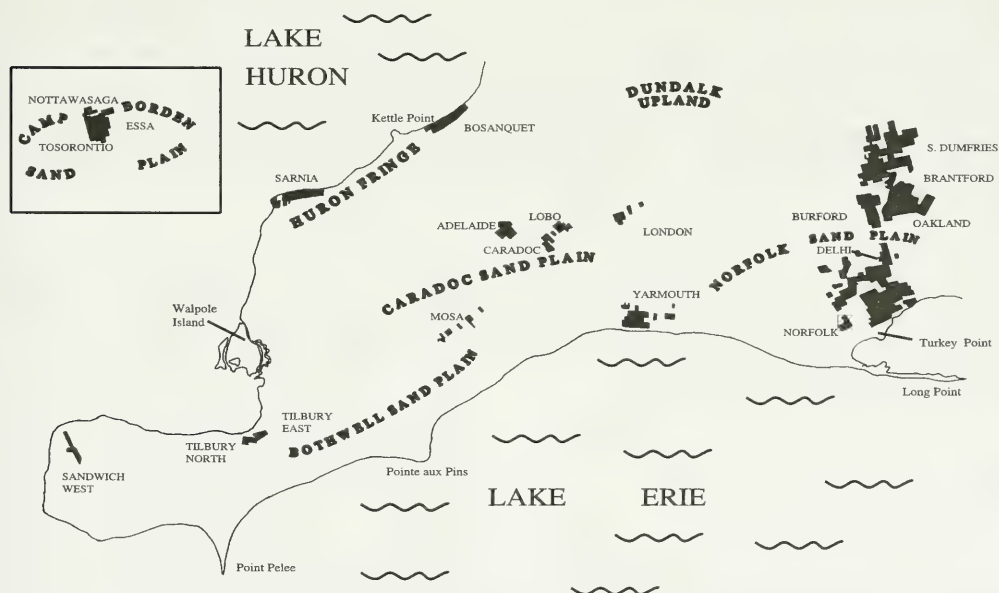


FIGURE 3. Putative late 18th and early 19th century geographic distribution of *Tachysphex pechumani* (black areas) in southwestern Ontario based on amount of sand plain and oak, White Oak, oak & hickory and oak & pine plains. Inset is Camp Borden Sand Plain. Sites without wasp habitation history are omitted (W. D. Bakowsky, personal communication 1997; Chapman and Putnam 1984; Varga and Schmelefske 1992; Varga 1992).

TABLE 2. Estimated hectarage of suitable habitat [oak/pine plains, scrub, burnt woodland] for *Tachysphex pechumani* in southwestern Ontario at the time of early settlement.

Area/Township	Number of hectares
Norfolk Sand Plain	48269*
Camp Borden Sand Plain	7000
Caradoc Sand Plain	4282
Sarnia	2500
Bosanquet	1500–3000
Tilbury North-Tilbury East	1100
Sandwich West [Windsor]	1052
London	615
Mosa	574**

*Estimated at 202.5 acres ÷2.471 hectares per lot for 589 lots

**Discontinuous hectarage

(Coakley 1989, 1992; Lewis et al. 1994) probably provided the added atmospheric moisture needed to raise the incidence of convective thunderstorms in the region. The droughty sands of southwestern Ontario coupled with the dry lightning strikes may have promoted periodic natural fires that: (1) impeded the growth of the mesophytic tree species; and (2) maintained sandy openings within oak and White Pine woodland and savanna for wasp habitation.

Fire-maintained oak, oak-White Pine and White Pine-Red Pine (*Pinus resinosa*) woodland, savanna and barrens persisted on the coarse-textured soils of southern Ontario until early Euro-Canadian settlement (W. D. Bakowsky, personal communication 1997; Szeicz and MacDonald 1991; Varga and Schmelefske 1992). Frequent lightning and native-set fires probably perpetuated these vegetation assemblages through the late Holocene (Catling et al. 1992; Cwynar 1978). These fires were enhanced by: (1) vast expanses of well to excessively drained, nutrient-impoverished, predominantly acidic sandy and gravelly soils inducing droughty conditions; (2) level to mildly undulating, low elevational topography providing few natural firebreaks; and (3) windward position of the land with respect to Lakes Erie and Ontario diminishing the amount of precipitation (Kurczewski 1998).

Late 18th and Early 19th Century Wasp Distribution

Tachysphex pechumani probably inhabited the same areas in southwestern Ontario at the time of early Euro-Canadian settlement as it does now but had a more extensive range (Figure 3). In this context, information on soils and vegetation obtained from late 18th and early 19th century land survey field note books and maps is presented for: (1) Brant, Elgin and Norfolk Counties [Norfolk Sand Plain]; (2) Bosanquet

Township in Lambton County [Pinery Provincial Park and vicinity]; and, (3) Essa, Nottawasaga and Tosorontio Townships in Simcoe County [Camp Borden Sand Plain]. Areas where *T. pechumani* probably occurred historically but is now extinct (Sarnia Township in Lambton County; Essex, Kent and Middlesex Counties) are included. Another area [Petawawa Township (Petawawa Sand Plain) in Renfrew County] with an extensive amount of coarse sandy soil, pine plain, fire history but no wasp record is also described. Late 18th and early 19th century information for three extensively sandy areas with no history of wasp habitation is presented to illustrate potentially unsuitable habitat: (1) along Nottawasaga Bay from Wasaga Beach to Balm Beach in Simcoe County; (2) Hepworth Sand Dunes in Keppel Township, Grey County; and (3) Murray Sand Hills in Murray Township, Northumberland County.

Norfolk Sand Plain

The Norfolk Sand Plain probably supported the largest late 18th and early 19th century population of the Antenna-waving Wasp in southwestern Ontario based upon extent of sandy soils, levelness of terrain, paucity of natural firebreaks and amount of contiguous suitable habitat (Figures 3, 4; Tables 2, 3). This sand plain has 313 000 ha of predominantly sandy soils in Norfolk, eastern Elgin, southern Brant and southeastern Oxford Counties (Chapman and Putnam 1984). It supported extensive oak, oak-hickory (*Carya* spp.) and oak-pine plains; scrubby, bushy, shrubby, open burnt, burnt and mostly burnt oak/pine vegetation; and oak and pine woods at the time of early Euro-Canadian settlement (Kurczewski 1998; Szeicz and MacDonald 1991). At least 1181 of 2000 lots in this region were oak and/or pine-dominated (Figure 4). Of these 1181 lots, 589 (49.9%) supported open plains, stunted oak/pine vegetation and/or burnt woods (Table 3). Prairie and savanna occupied 31 700 ha of the

TABLE 3. Number of lots of suitable habitat for *Tachysphex pechumani* in the Norfolk Sand Plain (Brant, Elgin, Norfolk Counties) at the time of early settlement*.

Type of habitat	No. Lots	%
Open oak, oak-hickory, oak-pine plains**	528	44.7
Small, scrubby, scrubbed, shrubby or bushy oak-pine/pine-oak thickets**	49	4.2
Burnt, mostly burnt or open burnt woods**	12	1.0
Oak-pine/pine-oak woods	95	8.0
Oak, oak-hickory or oak-cherry woods	260	22.0
Pine [White Pine?] woods	237	20.1
Totals	1181	100.0

*Derived from summary survey maps provided by W. D. Bakowsky (personal communication 1997)

**Most favorable wasp habitat

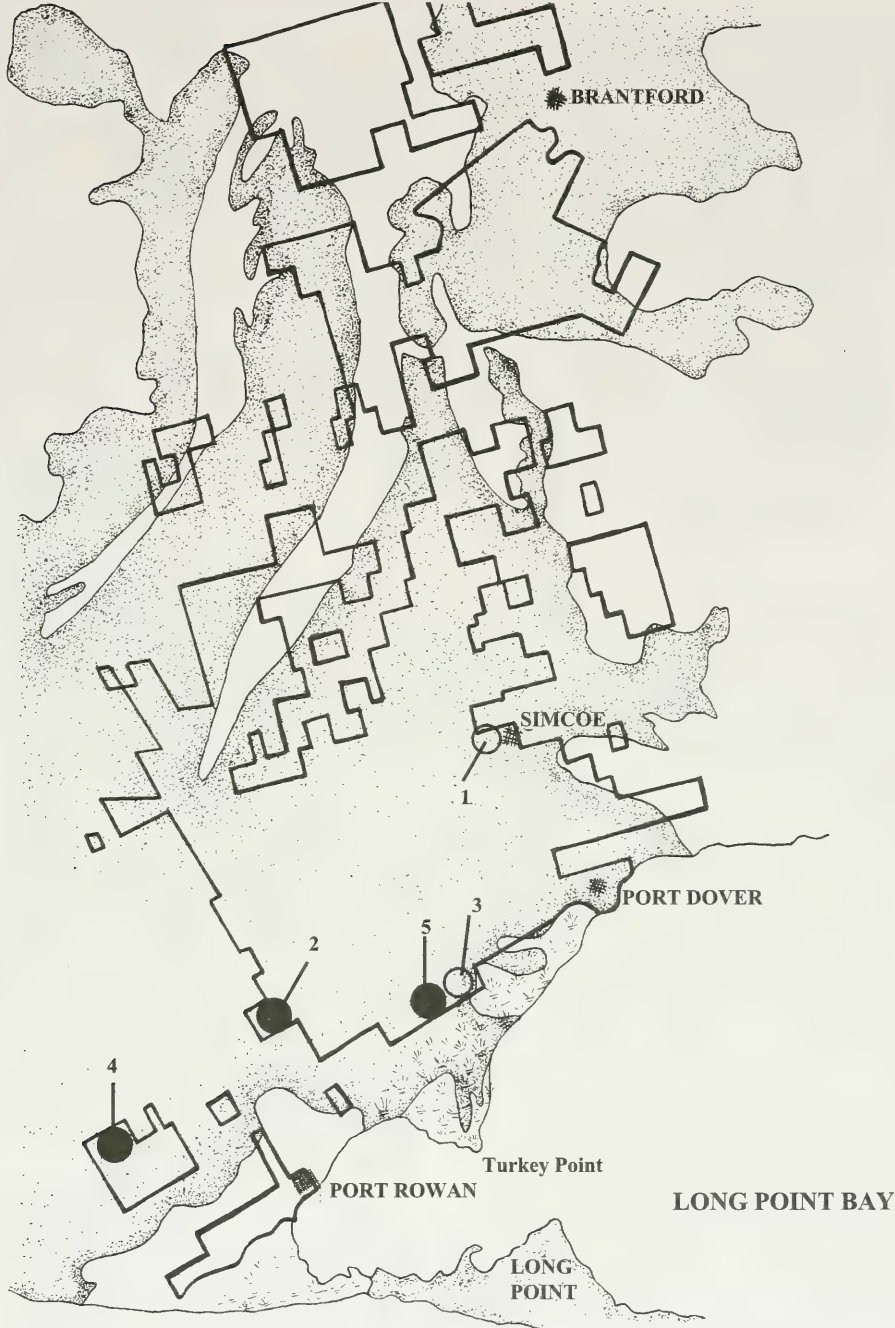


FIGURE 4. Present-day (black circles) and historic (open circles) *Tachysphex pechumani* nesting sites in the Norfolk Sand Plain as numbered: (1) Simcoe Junction; (2) St. Williams Crown Forest Manestar Tract; (3) Turkey Point Provincial Park; (4) South Walsingham Sand Ridges; (5) St. Williams Crown Forest Turkey Point Tract. Bold lines delimit oak and pine woods; scrubby, bushy and shrubby oak-pine vegetation; oak, oak-hickory and oak-pine plains; and open burnt, burnt and mostly burnt land in late 18th and early 19th century land surveys (W. D. Bakowsky, personal communication 1997). Limit of Norfolk Sand Plain is stippled (Chapman and Putnam 1984).



FIGURE 5. Predominant vegetation and topographic features in early 19th century Bosanquet Township (MacDonald 1835*). Vegetation types included deciduous forest (full canopy deciduous tree symbol at lower left), deciduous-coniferous forest (mixed tree symbols at upper right), pine-oak forest (pine and open canopy deciduous tree symbols below pine-oak plains), pine-oak plains and marsh/swamp. Limits of Pinery Provincial Park, Karner Blue Sanctuary, Watson Property and Ausable-Bayfield Conservation area are shown as dashed lines. *Tachysphex pechumani* nesting sites are indicated by grey circles numbered: (1) Pinery Provincial Park; (2) Karner Blue Sanctuary; (3) Watson Property; (4) Ausable-Bayfield Property.

Norfolk Sand Plain at the time of initial Euro-Canadian settlement (W. D. Bakowsky, personal communication 1997).

Removal of large stands of pine and oak, repeated fires following logging and land clearance for agriculture by the early European settlers denuded this sandy soil. The small amount of soil nutrients soon became exhausted, wind erosion ensued and many farms were abandoned. By 1900, 90% of the woodland in southern Norfolk County was removed and

much of the area comprised blow-sand (Beazley and Nelson 1993). Tobacco became the leading crop because it grew well in this warm, wind swept, predominantly barren droughty soil. Land not used for growing tobacco or other crops was often reforested with conifers (Chapman and Putnam 1984; Maycock 1963). The removal of the forest, subsequent fires and land clearance probably aided in the dispersal of *T. pechumani*. However, reforestation was detrimental to the wasp as it supplanted the savanna and openings used for mating, hunting and nesting (Kurczewski 1998).

Bosanquet Township

The area from Grand Bend to Ipperwash in Bosanquet Township is dominated by a series of sand dunes running parallel to Lake Huron (Chapman and Putnam 1984). Although 15 km long and 2.5 km wide, this area provided only 1500-3000 ha of suitable habitat for *T. pechumani* at the time of early Euro-Canadian settlement (Table 2). Pinery Provincial Park has 2319 ha of undulating sand dunes and level sand (T. J. Crabe, personal communication 1996), but dunes are inappropriate habitat for this species. The Lambton Wildlife Inc., Karner Blue Sanctuary; Lambton Wildlife Inc., Watson Property; and Ausable-Bayfield Conservation Authority

TABLE 4. Kilometers of suitable habitat [oak/pine woodland, burnt woods, open plains] for *Tachysphex pechumani* recorded in early settlement southern Ontario land surveys*

Area	Kilometers
Bosanquet Township	17.040
Sarnia Township	15.198
Camp Borden Sand Plain	46.481
Petawawa Sand Plain	24.220
Wasaga Beach-Balm Beach	3.802
Murray Sand Hills	3.239

Derived from MacDonald (1835); Mount (1829*); Benson (1820*); Black (1822*); and Rankin (1833*); Hamilton (1854*, 1856*); Goesman (1822a*, 1822b*) and Hawkins (1833*); and Grant (1794*), respectively

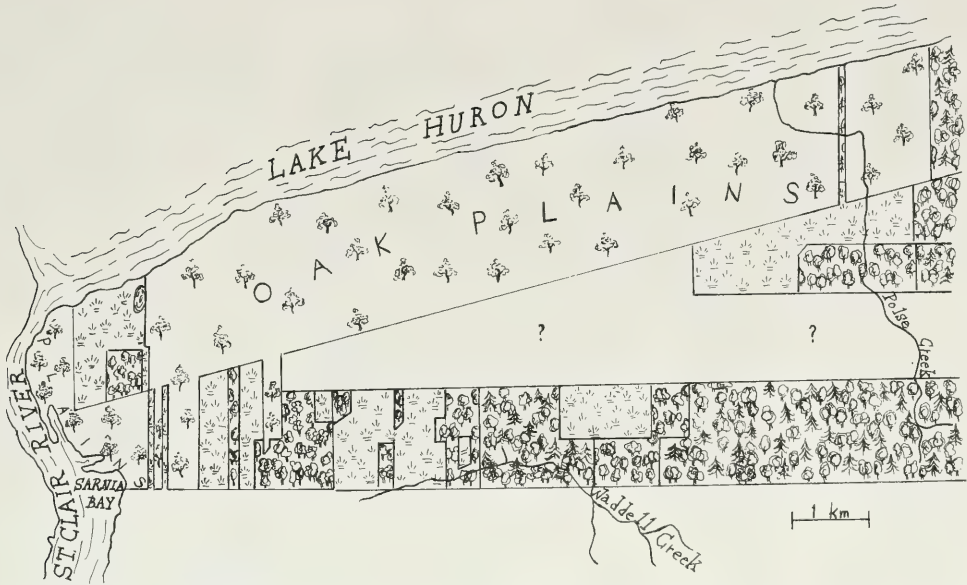


FIGURE 6. Predominant vegetation and topographic features in early 19th century St. Clair [Sarnia] Township (Mount 1829*). Vegetation types included deciduous (lower left, upper right) and deciduous-coniferous (lower right) forests, swamp and oak plains. Symbols used follow Figure 5.

Property combined have much less favorable habitat than this (Figure 5). The Karner Blue Sanctuary, for example, has fewer than 35 ha of suitable habitat (Sutherland and Bakowsky 1995).

According to early 19th century land survey field note books and maps (MacDonald 1835*), the area from just west of Grand Bend to just west of Port Franks had suitable habitat for the Antenna-waving Wasp along 17.040 surveyed km of concession and lot lines and side roads (Table 4). The predominant timber trees on 36 contiguous lots and sublots of undulating sandy hills (dunes), ridges and flats were pine, oak and poplar (*Populus* spp.) (22 lots and sublots); pine and oak (6); Red Pine, White Pine and oak (4); Red Pine, White Pine, oak and poplar (2); oak, pine and poplar (1); and scrubby Red Pine (1)(Figure 5). There was no mention of oak or pine plains in any of these lot descriptions. However, W. D. Bakowsky (personal communication 1997) is convinced that such plains existed north of the Old Ausable Channel based upon early 19th century surveys of the shoreline (Figure 5). *Tachysphex pechumani* probably inhabited these plains at that time because it nests in the area today.

Sarnia Township

Sarnia Township to the west of Bosanquet Township had 2500 ha of continuous sandy soil along

Lake Huron in the early 19th century (Table 2). Approximately 12 km of sandy beaches extended from Brights Grove to Point Edward. Sand dunes from earlier Lake Nipissing transgression were located farther inland, parallel to the Lake Huron shoreline (Chapman and Putnam 1984).

Sarnia Township probably once held a subpopulation of *T. pechumani*, although the wasp was not found there in 1995-1997. This assumption is based on the prevalence of level sandy openings, extent of oak-dominated plains and scarcity of natural fire-breaks at the time of early Euro-Canadian settlement; proximity (35 km) of the area to nesting aggregations near Port Franks in Bosanquet Township; and two historical collection records from Oakland County, Michigan, west of Lake St. Clair (M. F. O'Brien, personal communication 1991; Pulawski 1988).

The vegetation on 90 essentially contiguous sandy lots and sublots in Sarnia Township in the early 19th century consisted of "Red Oak [Black Oak] and White Oak Plains" (16 lots and sublots); "White Oak, Red Oak and Sassafras [*Sassafras albidum*] Plains" (11); "Red Oak, White Oak and Sassafras Plains" (9); "Red Oak Plains" (8); "Dry Sandy Plains" (8); "Red Oak, Sassafras, Pine and White Oak Plains" (7); "White Oak and Red Oak Plains" (5); "Red Oak and Sassafras Plains" (5); "White Oak Plains" (4); "Scrub Oak Plains" (3); "White Oak and Red Oak Woodland" (3); "White Oak, Red Oak,

*See Documents Cited section.

NOTTAWASAGA



FIGURE 7. Predominant vegetation and topographic features on the early 19th century Camp Borden Sand Plain (Benson 1820*; Black 1822*; Rankin 1833*). Vegetation types included deciduous-pine forest (upper center, lower right), deciduous forest (upper and lower center), pine forest (lower left, upper center), swamp and pine plains. Symbols used follow Figure 5. Long vertical line to right of center separates Tosoronto and Essa townships. Diagonal line near top delimits the southern boundary of Nottawasaga Township. Mad (upper) and Pine (lower) Rivers are shown but not labelled. Limit of C. F. B. Borden is indicated by dashed line. *Tachysphex pechumani* nesting sites are designated by black circles numbered 1-5 corresponding to order in text.

Sassafras and Pine Plains" (2); "White Oak, Red Oak, Sassafras and Pine Woodland" (2); "Pine, White Oak, Red Oak, Birch [*Betula*] and Sassafras Woodland" (2); "White Oak, Red Oak and Sassafras Woodland" (1); "Red Oak, White Oak, Sassafras and Pine Plain" (1); "White Oak, Pine, Red Oak and Sassafras Woodland" (1); "White Oak, Red Oak, Pine and Sassafras Woodland" (1); and "Oak Plain" (1)(Mount 1829*)(Figure 6). These vegetation types

grew along 15.198 surveyed km of concession and lot lines and side roads (Table 4).

Essex, Kent and Middlesex Counties

Disjunct subpopulations of *T. pechumani* probably inhabited sections of Sandwich West and Tilbury North – Tilbury East Townships in Essex and Kent Counties; and Mosa, Adelaide, Lobo, Caradoc and London Townships on the Bothwell and Caradoc

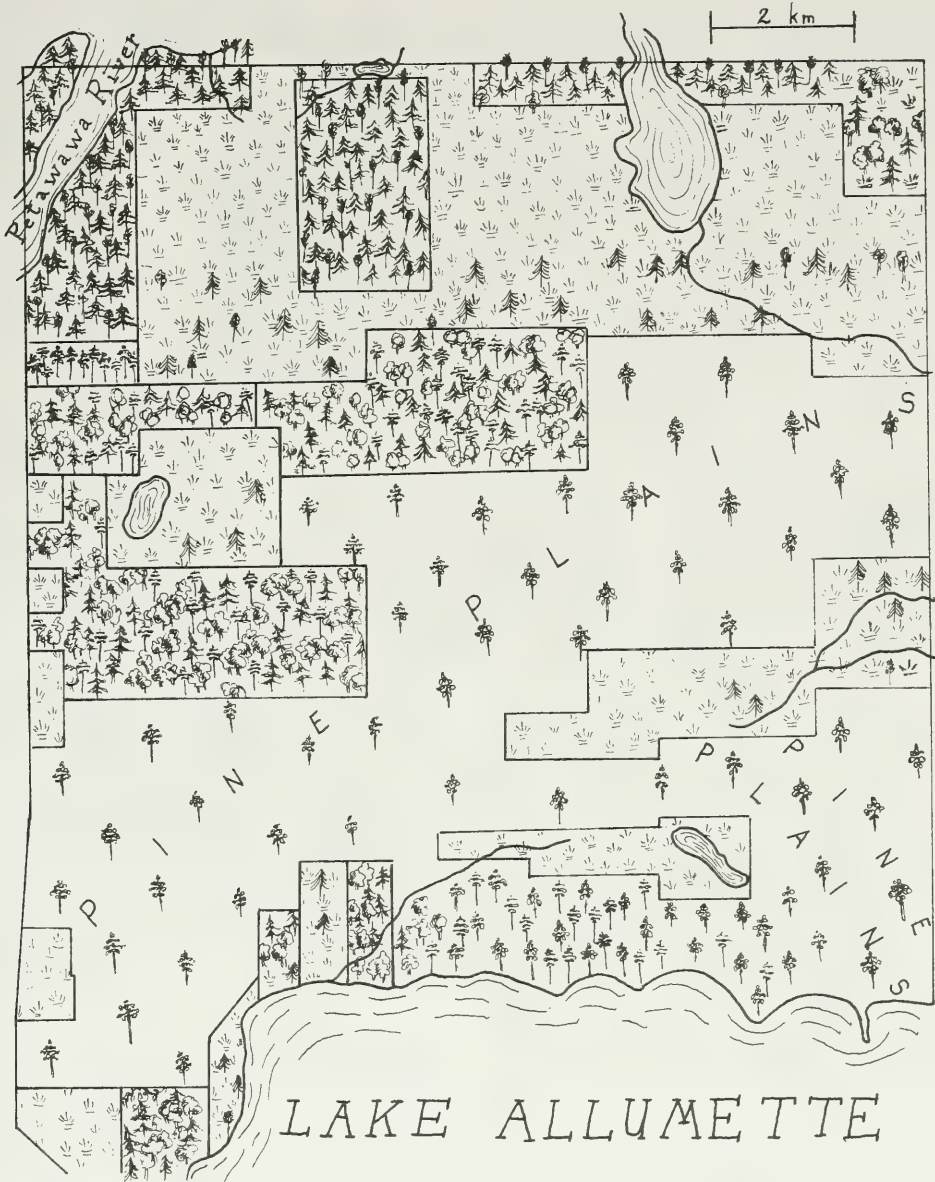


FIGURE 8. Predominant vegetation and topographic features in the 1850s on the Petawawa Sand Plain in Petawawa Township (Hamilton 1854*, 1856*). Vegetation types included coniferous forest [spruce and pine tree symbols (upper left)], deciduous-coniferous forest (left center, upper center), pine forest (lower center), pine plains, swamp and ponds. Symbols used follow Figure 5. Although not indicated, much of the upper (southern) pine plain was burnt.

Sand Plains in Middlesex County in the early 19th century. This assumption is based on the extent of dry sandy soils (Chapman and Putnam 1984) and oak-dominated plains in these areas (W. D. Bakowsky, personal communication 1997)(Figure 3; Table 2). These subpopulations were presumably

extirpated by agricultural practices and land development which completely dominate the area today.

Camp Borden Sand Plain

The Camp Borden Sand Plain probably supported a large population of *T. pechumani* in the early 19th

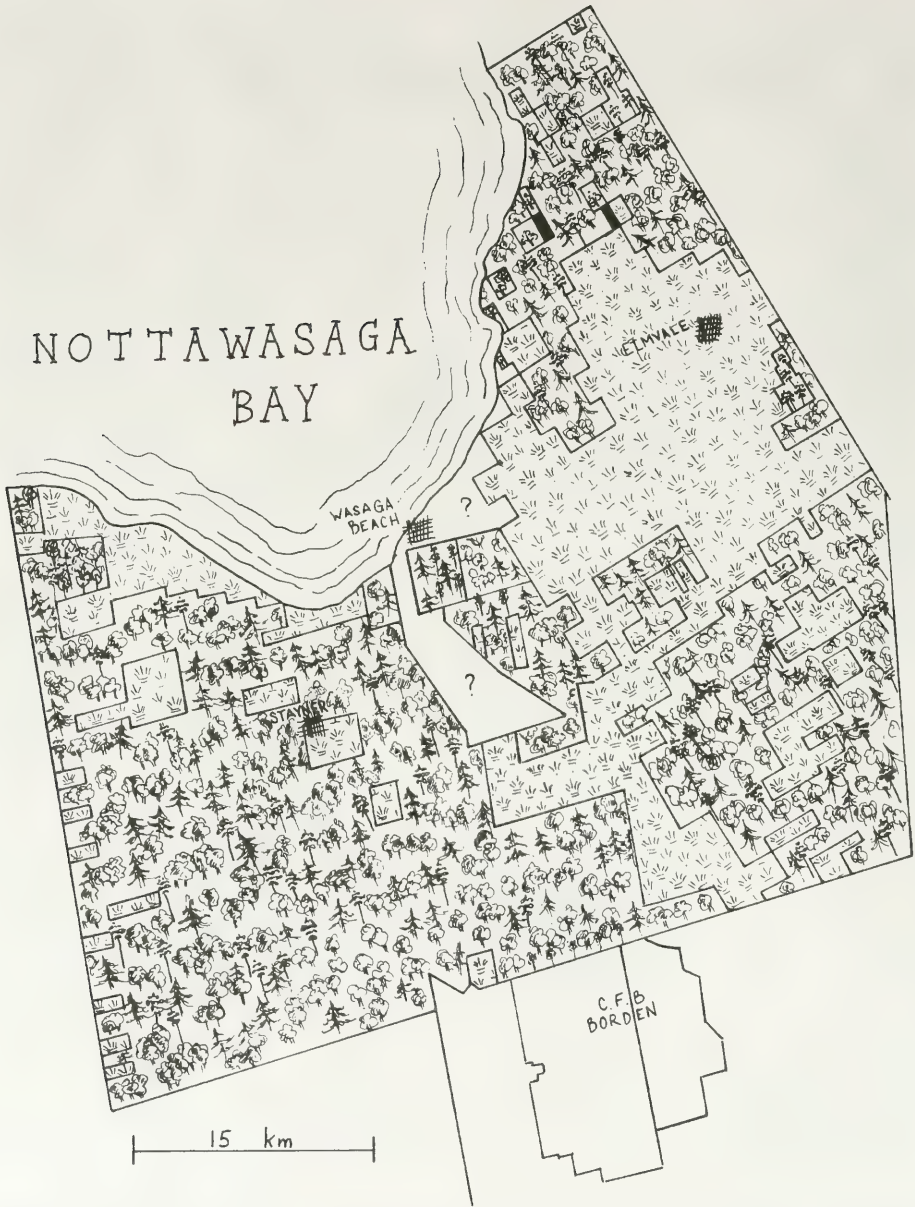


FIGURE 9. Predominant vegetation and topographic features in the Townships of Nottawasaga, Sunnidale, Vespra, Flos and Tiny and the Town of Wasaga Beach (in part) in the early 19th century (Goesman 1822a*, 1822b*; Hawkins 1833*; Rankin 1833*). Vegetation types included deciduous-coniferous forest (lower left, lower right), coniferous forest (upper center), swamp, White Pine (?) plain (two small patches near northeastern boundary line), stunted oak-pine woodland (scattered small blocks northeast of Wasaga Beach) and burnt land (small blackened rectangles). Symbols used follow Figure 5. Location of Camp Borden is shown below southern border of Nottawasaga Township.

century according to the extent of droughty sandy soils, fire history and amount of continuous pine plains (Figures 3, 7; Table 2). This sand plain has

30 554 ha of level and undulating, excessively drained, nutrient-impovertished, predominantly acidic loamy sand. Some of the land was cleared

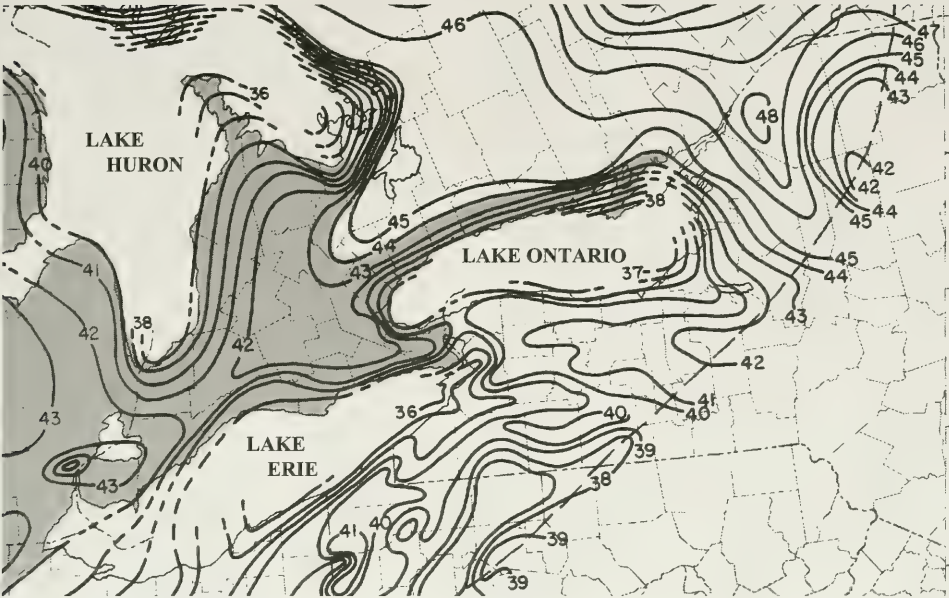


FIGURE 10. Isoplethic patterns of continentality coefficient < 44% (shaded area) (Kopec 1965).

early for farming but was abandoned because the droughty soils could not sustain an agricultural economy (Chapman and Putnam 1984). The coarse loamy sand of this sand plain supported extensive Red Pine and White Pine forest, savanna and barrens prior to Euro-Canadian settlement. The Red Pine forest was among the largest in southern Ontario south of the Canadian Shield. The droughty sands of the area promoted ground and crown fires that maintained this forest (Varga and Schmelefske 1992). An outline of the Red Pine forest matches closely the present borders of Base Borden (Figure 7).

Parts or entire sections of 94 mainly adjoining sandy lots supported “yellow pine” [Red Pine],

“chiefly yellow pine,” “yellow & white pine,” “yellow pine & a few white pine,” “white & yellow pine,” “white & yellow pine interspersed with openings,” “plains,” “pine plains,” “pine plain,” “plains of pine,” “open pine land,” “open pine plains,” “open plain with a few scorched pines,” “white pine plains,” “white & yellow pine plains,” “yellow pine plains,” “a beautiful plain of yellow pine,” “yellow pine windfall,” “pine windfall,” and “windfall” as described in the early 19th century land survey field note books for Tosoronto, Nottawasaga and Essa Townships (Benson 1820*; Black 1822*; Rankin 1833*)(Figure 7). This type of vegetation occurred along 46.481 surveyed km of concession and lot



FIGURE 11. Average annual precipitation minus evapotranspiration < 300 mm (stippled area) (Winter and Woo 1990).



FIGURE 12. Average soil moisture as a function of precipitation, evapotranspiration and temperature < 40 mm (stippled area) (Webb et al. 1993).

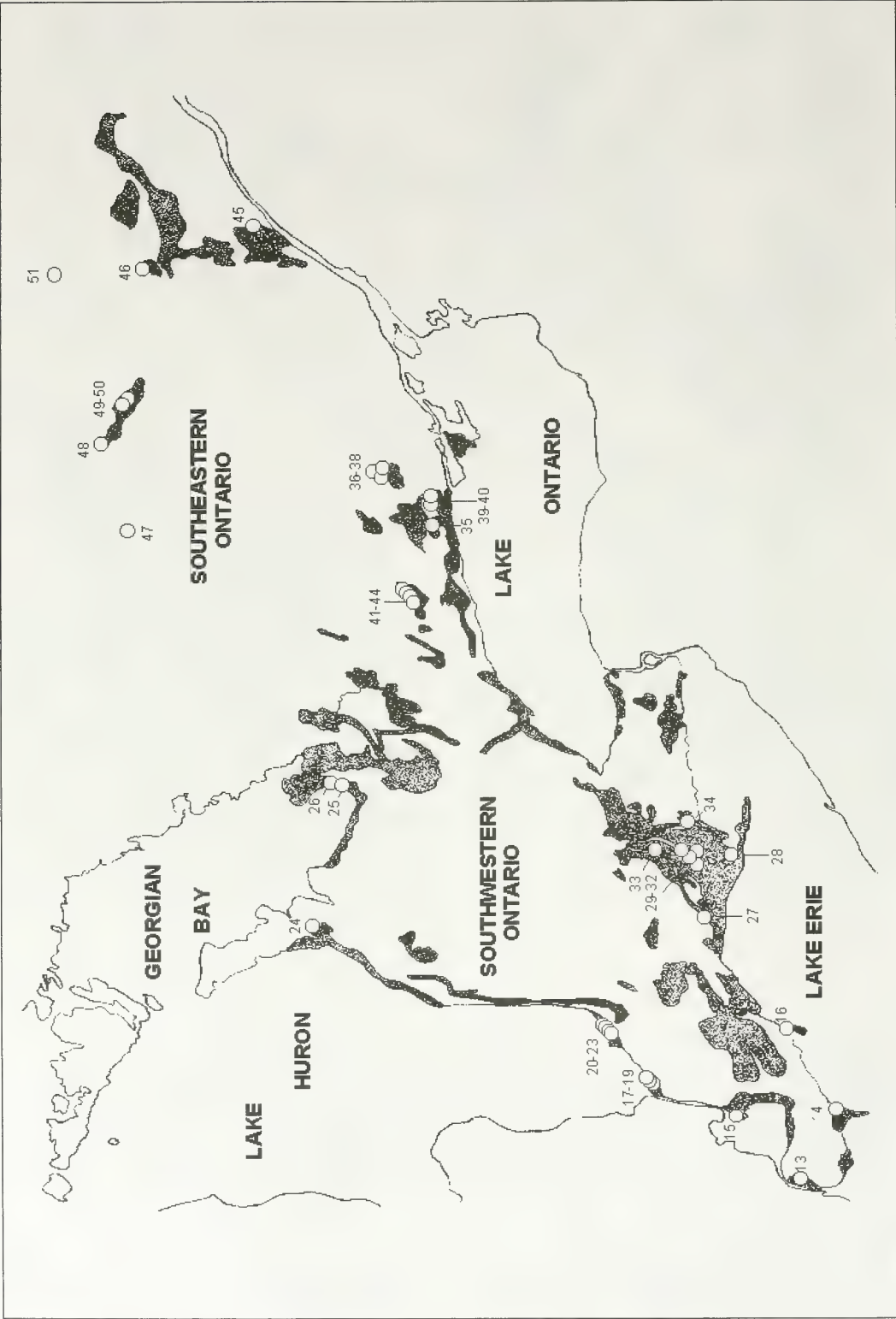


FIGURE 13. Current geographic distribution of *Tachysphex pechumani* in southwestern Ontario. Open squares denote locations of nesting aggregations as numbered: South Walsingham Sand Ridges (1); St. Williams Crown Forest Manestar Tract (2); St. Williams Crown Forest Turkey Point Tract (3); Pinery Provincial Park (4); Karner Blue Sanctuary (5); Watson Property (6); Ausable-Bayfield Property (7); and Canadian Forces Base Borden (8–12). Numbered open circles denote localities which appeared suitable edaphically but where *T. pechumani* was not found: ESSEX COUNTY: Ojibway Prairie Nature Preserve, Windsor (13); Point Pelee National Park (14); KENT COUNTY: Walpole Island Indian Reserve (15); Rondeau Provincial Park (16); LAMBTON COUNTY: Cantara Park, abandoned railroad bed, gravel pit-landfill, Sarnia (17–19); Kettle Point Indian Reserve; Ipperwash Provincial Park; Ipperwash Indian-Military Reserve (20–23); GREY COUNTY: Hepworth Sand Dunes, Hepworth (24); SIMCOE COUNTY: Wasaga Beach Provincial Park (25); Wasaga Beach to Balm Beach (26); ELGIN COUNTY: Port Burwell Provincial Park (27); HALDIMAND-NORFOLK REGIONAL MUNICIPALITY: Long Point Provincial Park (base) (28); Delhi; Nixon Black Oak Knoll; Simcoe Junction; Trout Creek Valley (29–32); Vanessa Swamp (33); Port Dover (34); NORTHUMBERLAND COUNTY: Goodrich-Loomis Conservation Area, Orland (35); Sager Sand Barren; Stirling Sand Barren; Sand Barren # 8 (Cading and Cading 1993) (36–38); Smithfield; Murray Sand Hills, Trenton (39–40); Centreton; Burnley; Alnwick Indian Reserve, Alderville; Plainville (41–44); GRENVILLE COUNTY: Spencerville Sand Barren (45); REGIONAL MUNICIPALITY OF OTTAWA-CARLETON: Constance Bay (46); RENFREW COUNTY: Barry's Bay (47); Chalk River (48); Petawawa Forestry Research Station; Canadian Forces Base Petawawa (49–50); WRIGHT COUNTY (QUEBEC): Kazabazua (51). Darkly stippled areas delimit sand plains following Chapman and Putnam (1984).

lines and side roads (Table 4). "Open barrens" designated on a map of 1820s vegetation on this sand plain (Varga 1992) probably sustained the wasp aggregations through pre-colonial times. Military activity at Camp Borden maintained the savanna and barrens through the 20th century.

Petawawa Sand Plain

An estimated 33 670 ha of sandy soil occupy the Ottawa River Valley between Pembroke and Deep River. Petawawa Township west of the Petawawa River including Canadian Forces Base (C. F. B.) Petawawa had 24.220 surveyed km of pine plains and burnt and stunted pine woodland along concession and lot lines and side roads at the time of early Euro-Canadian settlement and logging (Table 4). The predominant vegetation on 72 adjoining sandy lots comprised "Red Pine," "Red & White Pine," "Small Red Pine," "Small Red Pine & Poplar," "Dwarf Pine," "Small Pine," "Small timber," "Little timber," "Plains," "Pine Plains," "Red Pine Plains," "scattering Dwarf Pine mostly burnt," "Dwarf Pine burnt," "Dwarf Pine scorched," "Charred Pine," "Dead Pine," "Pine and Birch burnt," "Timber mostly burnt," "Timber burnt," "Timber dead," "no timber-Burnt," and "No timber" (Hamilton 1854*, 1856*) (Figure 8).

The Antenna-waving Wasp was not found at C. F. B. Petawawa despite soil and early settlement timber similar to C. F. B. Borden. Camp Petawawa is located nearly 2° latitude farther north than C. F. B. Borden, is not tempered climatically by the Great Lakes, has an average annual temperature 2°C colder than Camp Borden, has a more boreal fauna and flora (Carbyn and Catling 1995), and is situated nearly 300 km across the Canadian Shield — well outside of the present-day range of *T. pechumani*.

Wasaga Beach to Balm Beach

Submarginal habitat for *T. pechumani* runs along Nottawasaga Bay for 25 km from Wasaga Beach Provincial Park to Balm Beach (Figure 9). This sandy rim is only 1 km wide in some places. It includes sandy beaches, dunes and flats and 1320 ha of the park. The area is located in the Town of Wasaga Beach, western Tiny Township and northwestern Flos Township. The region to the south and west in Nottawasaga, Sunnivale and most of Flos and Vespra Townships had much poorly drained sand, silt and clay underlying bogs, marshes, swamps and other wetland at the time of early Euro-Canadian settlement (W. D. Bakowsky, personal communication 1997) (Figure 9). Many of these lots were described as low, largely wet, swampy or unfit for cultivation (Goesman 1822a*; Hawkins 1833*; Rankin 1833*). Such terrain probably thwarted the dispersal of *T. pechumani* through this region despite the proximity to C. F. B. Borden. The Antenna-waving Wasp was not found at Wasaga Beach Provincial Park or vicinity during

seven collecting and observational trips in late June and/or July 1995, 1996, 1997, 1998 and 1999.

Unfortunately, most of the early 19th century lot descriptions for the Town of Wasaga are missing (W. D. Bakowsky, personal communication 1997). Nonetheless, parts of only eight of 517 (1.5%) lots described in the early 19th century field note books and maps for this town and the Townships of Tiny, Flos, Vespra, Sunnidale and Nottawasaga were marginally suitable for *T. pechumani* habitation (Figure 9). They included 3.802 mainly discontinuous surveyed km along concession and lot lines and side roads (Table 4). These eight lots were located near Nottawasaga Bay and supported scrubby pine and/or oak brush, birch, fir (*Abies balsamea*) and/or cedar (*Thuja occidentalis*?) growing on wind swept sand dunes and gravelly beaches, both inappropriate habitat for *T. pechumani*. Parts of two other lots located farther inland had burnt pine and mesophytic deciduous species (Goesman 1822b*).

Hepworth Sand Dunes

The Hepworth Sand Dunes are a northern extension of the Huron Fringe with much blow-sand (Chapman and Putnam 1984). The area probably once supported coniferous-deciduous forest as large maple (*Acer* sp.) trees still project above this pine-reforested site. Coniferous-deciduous forest, swamp and lowland surrounded the area according to early 19th century land survey maps (W. D. Bakowsky, personal communication 1997). There was no indication of oak/pine plain or woodland. *Tachysphex pechumani* was not found here in 1996 or 1997 nor were specimens located among 1995-1998 Hepworth Sand Dunes Malaise trap samples (S. A. Marshall, personal communication 1998).

Murray Sand Hills

The Murray Sand Hills support small patches of oak savanna containing White Oak, Northern Red Oak, White Pine, Eastern Red Cedar (*Juniperus virginiana*), Quaking Aspen (*Populus tremuloides*), Black Cherry (*Prunus serotina*), and Bracken Fern (*Pteridium aquilinum*). These openings evidently resulted from modern human disturbance because large White Oak, Northern Red Oak, Sugar Maple, Basswood, White Ash and White Pine trees with an undergrowth of Wild Grape (*Vitis aestivalis*) surround these sites. The north boundary line of Murray Township at the time of early Euro-Canadian settlement was described as deciduous hardwood forest and White Pine interspersed with extensive swamp and lowland (Birdsall 1820*). The east boundary line of the township also supported swamp and deciduous-coniferous forest. Concessions 7 and 8 on the east boundary line had "Pine ridge wood low brush Pine poor sandy soil" running along 3.239 surveyed km prior to settlement (Grant 1794*) (Table 4). There are no late 18th or early 19th century sur-

vey field note books or maps for the interior of the township (W. D. Bakowsky 1997, personal communication). *Tachysphex pechumani* was not found at this site during three visits in late June and July 1995 and 1996.

Present-day Wasp Distribution

Tachysphex pechumani occurs only in sections of the Lower Peninsula of Michigan, northwestern Indiana, northwestern Ohio, southwestern Ontario and the New Jersey Pinelands National Reserve (see Figure 2, Kurczewski 1998; Kurczewski *in press*). Its range in the central Great Lakes Region is governed by: (1) vast acreage of low relief, well to excessively drained, nutrient-poor sandy soils; (2) frigid/mesic soil temperature regime; (3) climate moderation associated with temperate latitude, proximity to large bodies of water and peninsular land masses; (4) maximum coefficient of continentality of 44% (Kopec 1965) (Figure 10); (5) average annual precipitation minus evapotranspiration < 300 mm (Winter and Woo 1990) (Figure 11); (6) average soil moisture as a function of precipitation, evapotranspiration and temperature < 40 mm (Webb et al. 1993) (Figure 12); (7) frequent past lightning and human-caused fires; (8) presence of oak/pine woodland, savanna and barrens; and (9) abundance of prey grasshoppers of suitable size, stage and species (Kurczewski 1994*).

Tachysphex pechumani has three extant populations in southwestern Ontario: (1) Norfolk Sand Plain; (2) Bosanquet Township; and (3) Camp Borden Sand Plain (Figure 13). Within the Norfolk Sand Plain this species inhabits: (1) South Walsingham Sand Ridges; (2) St. Williams Crown Forest Manestar Tract; and (3) St. Williams Crown Forest Turkey Point Tract (Figure 4). The Antennawaving Wasp probably also lives in non-agriculturalized sandy areas between and just north of these localities. This species was Malaise trapped at Simcoe Junction (28 June 1994, J. T. Kerr); St. Williams Crown Forest Manestar Tract (21 June-2 July 1994, P. J. Carson); and Turkey Point Provincial Park (11-18 June 1986, L. Packer), all in the Norfolk Sand Plain (Figure 4). Dirt bike traffic in the 1990s destroyed the aggregation at Turkey Point Provincial Park and has nearly eliminated the one at the Manestar Tract. Removal of railroad ties and rails followed by bulldozing in 1996 extirpated this species from Simcoe Junction (Kurczewski 1998).

Eight females nested 22 June-21 July 1996 in the South Walsingham Sand Ridges in sandy openings in a dry old field allowed to succeed to its pre-Euro-Canadian settlement condition, a predominantly oak-White Pine woodland. One female excavated a resting burrow there on 21 July (P. J. Carson and M. E. Gartshore, personal communication 1996).

Four females were observed on 26 June and 26 July 1996 and 1 July 1997 in an open sandy area receiving heavy dirt bike traffic at the St. Williams Crown Forest Manestar Tract. Once a dry, mixed Red Maple-oak-White Pine forest (Sutherland and Bakowsky 1995), this area was disturbed almost to the exclusion of the wasp.

The St. Williams Crown Forest Turkey Point Tract had a dense aggregation of *T. pechumani* in 1996 on a sandy two-track beside an oak-pine savanna bordered by reforested Red Pine. More than 30 males occupied this site on 20 June. On 23 June, I noted 36 females and 24 males. By 26 June, 48 females were nesting there. The number of males was 19. One month later (26 July 1996), only seven females with frayed wings were observed walking wobbly, making short (6-8 cm-long) flights, excavating resting burrows and closing themselves inside at midday (air temperature, 21-22°C; sand surface temperature, 37-40°C). These behaviors are all signs of senescence. No nesting occurred during this 4-hour observation period.

On 29 June 1997 at the Turkey Point Tract, 36 females nested in an area of the two-track 70 × 3 m. Sixteen nest entrances were 11-31 cm apart. By 1 July 1997, 89 of 104 (86%) nests had been destroyed by dirt bikes (Kurczewski 1998). On 18 July 1998, only one wasp and five resting burrows were found there. Most (90%) of the site was run over by dirt bikes.

Tachysphex pechumani nested in four preserves in Bosanquet Township in 1996: (1) Pinery Provincial Park; (2) Karner Blue Sanctuary; (3) Watson Property; and (4) Ausable-Bayfield Property (Figure 5). This species was Malaise trapped at Pinery (18-24 June 1986, 22 June 1995; L. Packer).

Three sightings of *T. pechumani* were made at Pinery Provincial Park in 1996. One male was collected on 27 June from a sandy utility right-of-way surrounded by oak woodland (see Darling and Packer 1988 for site description). Two females and their nests were observed on sand near the Carolinian Trail in an Eastern Red Cedar-oak savanna. The Antenna-waving Wasp was not seen in the park 29-30 June 1997.

Twenty-five females nested at the Karner Blue Sanctuary 27 June-4 July 1996 in sandy openings in "The Bowl" and a sandy two-track leading into the area. Both sites were surrounded by dry oak-pine woodland (see Sutherland and Bakowsky 1995 for site description). Five females with frayed wings were noted walking on the sand, excavating resting burrows but not nesting on 22-25 July 1996 (J. Skevington, personal communication 1996). Six wasps nested in "The Bowl" but none in the two-track 29 June-1 July 1997.

At least 25 females nested at the Watson and Ausable-Bayfield Properties 27 June-9 July 1996.

Eight wasps nested in one sandy opening. By 12-15 July, a few females were seen walking on the sand but none were nesting (J. Skevington, personal communication 1996). On 30 June 1997, I observed only one wasp at the Ausable-Bayfield site and none at the Watson Property.

The Antenna-waving Wasp nested at five sites on C. F. B. Borden (Figure 7). The species had not yet emerged when I first visited this locality on 28 June 1996. However, two widely separated nesting aggregations were found there on 26-28 July 1996. One aggregation held nine females, a male with frayed wings and 15 nests. Fourteen of the nests were located in an area of compacted sandy roadway, 9.5 × 2 m. The other nest was found 15.5 m away. Three entrances in the roadway were only 3-5 cm apart, but 11 others were spaced at distances of 9-50 cm. I located only two wasps and their nests at this site on 13-14 July 1997 and none on 5-7 or 18-19 July 1998 or 29 June-2 July 1999.

Two females and four nests were discovered at a second site on Camp Borden, a sandy two-track running through a Scot's Pine (*Pinus sylvestris*) savanna, on 26-28 July 1996. No wasps or nests were found there on 13-14 July 1997 or 5-7 or 18-19 July 1998. A third site held two females and five nests on 13-14 July 1997. Nest entrances were in a straight line and 5-14 cm apart. The presence of both gomphocerine and melanopline grasshoppers (Acrididae) in the cells indicated that nesting was midway through the season and phenologically ahead of 1996 at this locality. Species of Gomphocerinae often replace those of Melanoplineae as prey of *T. pechumani* in mid-season. This site was destroyed by military vehicles on 5 July 1998.

A fourth site comprised a sandy two-track running through a grassy field with scattered large White Pine, Jack Pine (*Pinus banksiana*) and Red Pine trees and Bracken Fern. It did not hold any wasps in 1996 or 1997 but had two groups of wasps nesting 32 m apart on 5-7 July 1998. Two females and six nest entrances, 10-120 cm apart, were located in one group. Five females and 12 entrances, 11-77 cm apart, were found in the southern aggregation. Seven of these nests were destroyed by truck traffic on 6 July 1998. Only one aging female was evident on 19 July 1998. She walked wobbly for 25 min while searching for a place to dig, excavated a resting burrow at 12:37 (air temperature, 25°C; sand surface temperature, 30°C) and then closed herself inside.

Two aggregations of wasps nested at this site in the same areas as in 1998 on 29 June 1999. Four males, five females and 15 nest entrances, 7cm - 2.1m apart, were located in the northern aggregation. Three females and 13 nest entrances, 9cm - 4.3m apart, were found in the southern aggregation.

A fifth nesting site was located at Camp Borden in

1998, 4 km NW of the second site. No wasps were found there on 6 July but a 7-10 day-old completed nest was discovered on 18 July in a sandy two-track running through a mixed pine-graminoid savanna.

Conservation Implications

The three southwestern Ontario populations of *T. pechumani* are persisting somewhat precariously (Kurczewski 1998). The population in Bosanquet Township seems to be closer to extinction than the other two populations because of previous fire suppression, deciduous forest expansion and excessive planting of conifers in oak savanna. Pinery Provincial Park, in particular, is in dire need of removal of woody vegetation to create openings for the Antenna-waving Wasp and other savanna species. Although having the smallest acreage of the four sites in Bosanquet Township, the Karner Blue Sanctuary appears to be the least threatened because of openings created by recent vegetation removal. Controlled burning was scheduled for the sanctuary in April 1999. Purchase of suitable habitat southwest of Pinery Provincial Park is recommended.

In the Norfolk Sand Plain, the South Walsingham Sand Ridges aggregation may have the best long-range chance of continuance because of less human interference. This area was not planted extensively with conifers or heavily disturbed by dirt bikes like the St. Williams Crown Forest. Few Antenna-waving Wasps are left in the Crown Forest due to reforestation and destruction of nests by extensive dirt bike traffic. Another serious problem for wasps in the Norfolk Sand Plain is the long-term use of insecticides on the local agricultural fields. No wasps were found near tobacco fields or at the edges of orchards despite seemingly favorable habitat. Purchase of suitable land and preservation, including fencing and surface bulldozing to create appropriate habitat, is recommended for this area.

The Camp Borden Sand Plain population of *T. pechumani* is only moderately safe from extirpation. Three of the five nesting aggregations at C. F. B. Borden were destroyed by military vehicular traffic during a three-year period. A fourth site will disappear soon as a result of vegetation succession. On a positive note, fire suppression and insecticide spraying pose no threat to the species at Camp Borden. In fact, periodic fires caused by military activity have replaced the prevalent lightning-strike and native-set fires of the pre-colonial White Pine-Red Pine forest period. Military-induced fires and other land clearance activities maintained the barrens and savanna.

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Partial Consumption of Shield Fern, *Dryopteris dilatata*, Rhizomes by Black-tailed Deer, *Odocoileus hemionus sitkensis*, and its Potential Implications

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Based on observations of tractable free-ranging deer, the rhizomes of Shield Fern (*Dryopteris dilatata*) are an important winter food for Black-tailed Deer (*Odocoileus hemionus sitkensis*) in coastal southeastern Alaska. To examine the effects of this herbivory on subsequent vegetative growth, in late winter we marked 71 *Dryopteris* rhizomes for which we knew the proportion of the rhizome that had been consumed by foraging deer; we selected 51 control plants from a nearby site for comparison. Removal of any portion of the rhizome greatly reduced vegetative growth during the following summer. Plants with more than 25% of their rhizomes removed produced essentially no growth during the next growing season; removal of 1–25% of the rhizome greatly retarded growth of the ferns and sometimes resulted in highly succulent forage being produced in September. The presence or absence of Shield Fern is used to distinguish plant communities in the Western Hemlock (*Tsuga heterophylla*) forest type, but abundance of this species can potentially be reduced by intensive deer browsing on rhizomes during mild winters.

Key Words: Black-tailed Deer, *Odocoileus hemionus sitkensis*, Shield Fern, *Dryopteris dilatata*, rhizome, feeding habits, plant communities, Alaska.

Herbivory can have severe impacts on vegetation. Some of the most dramatic effects of ungulates on vegetation, and consequently on the population dynamics of the ungulates themselves, occur when ungulates are introduced to island, predator-free environments (e.g., Klein 1968). There are, however, numerous other examples of the impacts of ungulate herbivory on vegetation (e.g., Brandner et al. 1990), litter accumulation (McInnes et al. 1992), plant reproductive biology (Allison 1990a, 1990b), and plant chemical composition (see review by Palo and Robbins 1991). Although the effects of herbivory are not limited to forested ecosystems (e.g., Oosterheld and McNaughton 1991; McNaughton 1992) nor specifically to mammals (e.g., Hik et al. 1991), much attention has been paid to aspects of mammalian damage to commercial timber species (e.g., Gill 1992). Consequently, biologists and foresters have invested heavily in the control of animal damage and in the methods of assessing repellent efficacy (e.g., Gillingham et al. 1987). Browsing by deer and other ungulates generally causes a decrease in above-ground shrub and herbaceous plant biomass (Gill 1992), and even when commercial species are not involved, deer have the potential to affect plant community structure.

With the advent of widely available geographic

information systems (GIS) for ecosystem mapping, there is increasing interest in the use of plant association and plant community classification for forest and wildlife management. Understory plants (e.g., ferns) are often used as part of these classification systems. In the Tongass National Forest (Alaska, USA), for example, plant associations provide a useful descriptive and predictive management tool for silviculture, for fish and wildlife habitat management (Martin and DeMeo 1989), and for understanding successional patterns across the landscape. Key plant species can be readily used to estimate habitat capability (Martin and DeMeo 1989). The presence or absence of Shield Fern (*Dryopteris dilatata*; Figure 1; synonymous with *D. expansa*; Cody 1996) is one of the species used to distinguish plant communities in the Western Hemlock (*Tsuga heterophylla*) forest type (Viereck et al. 1992).

Because direct observations of forage intake by free-ranging deer are usually difficult to obtain, dietary composition often is based on fecal analyses or signs of clipping or browsing on trees and shrubs. Ferns (i.e., *Dryopteris*, *Blechnum*, *Athyrium*) comprised a low percentage of the diet of Sitka Black-tailed Deer (*Odocoileus hemionus sitkensis*) throughout southeast Alaska based on fecal values (Hanley and McKendrick 1983) and the rhizomes of these

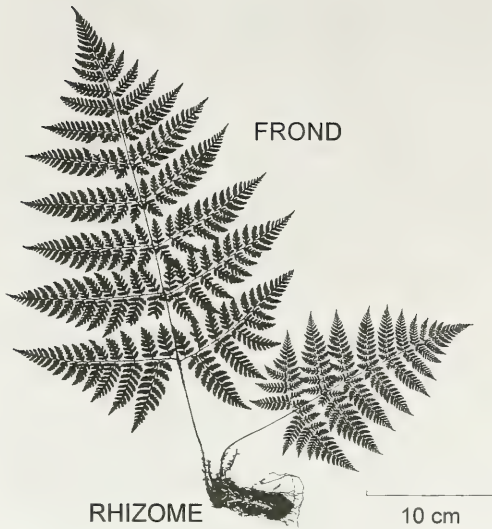


FIGURE 1. Scale drawing of a typical *Dryopteris dilatata* (synonymous with *D. expansa*; Cody 1996) plant indicating position and relative size of the frond and rhizome.

plants were not detected or reported in their diets. In a study of the nutritional ecology of Black-tailed Deer, we bottle-raised nine deer and weaned them onto the natural vegetation. Because we were able to observe these free-ranging, highly-tractable animals over a continuous two-year period, we documented extensive use of the rhizomes of *Dryopteris dilatata* during winter (Gillingham et al. 1997; Parker et al. 1999). Here we report on the consequences of consuming rhizomes on vegetative production during the following growing season.

Methods

As part of a larger foraging/bioenergetics study (Parker et al. 1993a, 1996, 1999), we conducted intensive field observations of hand-reared Black-tailed Deer on Channel Island 20 km southeast of Wrangell, Alaska (56°22'N, 132°10'W; see Parker et al. 1996 for details). Animals were completely dependent on their environment for their survival and allowed observers to follow within 1 m. Because they also allowed an observer to kneel next to them, we were able to make detailed observations of rhizome consumption. On 16 March 1990 we followed three animals while they were foraging for *Dryopteris* rhizomes. Because actual weights of the rhizomes could not be obtained before and after foraging by deer, we estimated the percentage of each rhizome removed. This percentage was based on a visual estimate of the amount removed by the deer using an accurate bite-unit technique (Parker et al.

1993b) and our visual inspection of the amount of rhizome remaining in the ground after deer moved to another forage item. Although this estimation was subjective, we were confident that we could estimate rhizome removal to the nearest 25% (i.e., 1-25%, 26-50%, 51-75% and 75-99%). Any rhizomes for which these estimates could not be made were eliminated from analyses given our objective to quantify vegetative regrowth following foraging by deer. We also did not monitor rhizomes that were completely (100%) removed by deer because these would always be associated with 0% regrowth.

We marked the locations of the 71 rhizomes for which we determined the amount of the rhizome removed by deer. By necessity, these rhizomes were all selected by deer and consequently are not a random sample, but rather all rhizomes located by deer during the observed foraging bouts. The following day we randomly selected and marked 51 control *Dryopteris dilatata* plants from an adjacent island, approximately two km by boat from our study area. We identified these control rhizomes based on their remaining above-ground vegetation. All control plants were growing at the same elevation and slope as those on Channel Island and the habitats appeared comparable in all respects except that the control area had minimal use by deer during winter.

We estimated seasonal changes in above-ground biomass of both "treated" and control plants on 21 April (no new growth observed), 2 May, 13 June, 28 July, and 20 September 1990 using a non-destructive plant-unit method (Parker et al. 1993b). A one-way ANOVA (PROC GLM: SAS 1987) was used to assess differences between control (0% removal) and all treated plants, and then between categories of removal: 0; 1-25%; 26-50%; 51-75% and 75-99%. Following one-way ANOVAs for the fiddlehead, frond, and total biomass in each of May, June, July and September, we used Tukey's range test (control of experiment-wise Type I error; Sokal and Rohlf 1995) to examine treatment differences if a significant overall effect of rhizome removal was detected.

Results

Foraging by deer on *Dryopteris* rhizomes during winter had a negative effect on the following season's vegetative growth (Figure 2). There was no vegetative production by treated or control plants in early April, but by May there was significantly more biomass in fiddleheads and fronds (and therefore total biomass) for all of the controls (0% removed; Table 1). Much of the early-season biomass in the control plants occurred as fiddleheads; by June nearly all of the biomass was in fronds (Figure 2). Therefore, although frond and total biomass of the controls remained significantly greater than the foraged plants through September, new fiddlehead growth dropped after May.

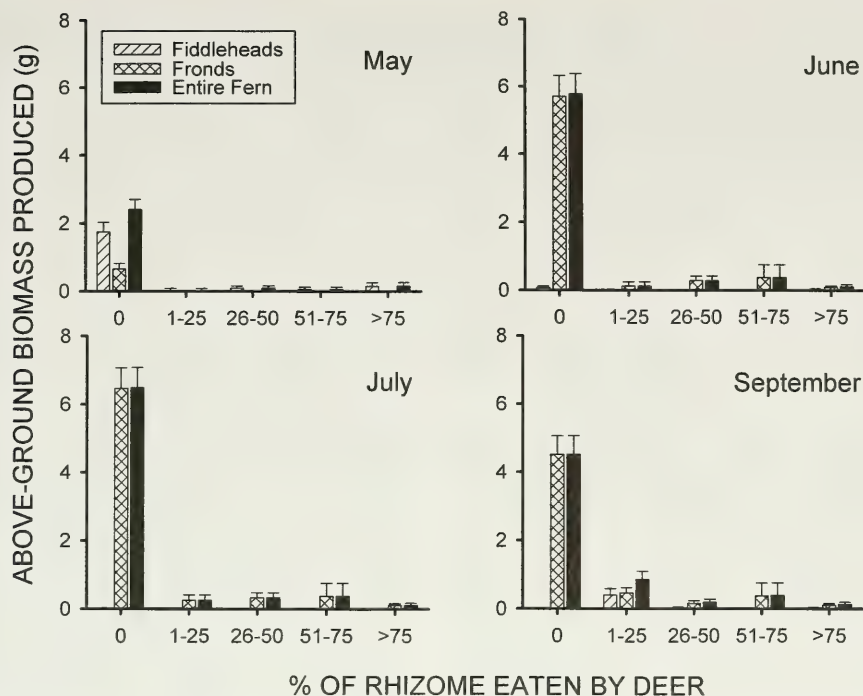


FIGURE 2. Effect of the amount of the *Dryopteris dilatata* rhizome removed by foraging Black-tailed Deer during winter on above-ground biomass ($\bar{x} \pm SE$) produced by the following May, June, July and September. The estimated biomass for the entire fern represents the sum of the estimated frond and fiddlehead biomass.

We observed almost no regrowth in any plants for which >25% of the rhizome was removed. Interestingly, plants that had 1-25% of their rhizomes removed, showed significant late fiddlehead production in September (Table 1) resulting in the production of very succulent forage late in the season. This biomass ($\bar{x} = 0.85g$), however, was only 18% of the mean biomass (4.52g) of the control plants in September (Figure 2). In addition our observations on foraging animals indicate that September-produced fiddleheads were highly selected by deer, compounding the impacts of herbivory on these plants.

Discussion

Wintering Black-tailed Deer appear to affect the vigour and abundance of *Dryopteris dilatata* by partially or entirely consuming rhizomes. Because of their high energy value, these rhizomes are very important to the energy balance of deer (Parker et al. 1996) even when consumed in relatively small quantities. We were only able to detect that deer were eating rhizomes when we were in close proximity to foraging animals. During our two-year study, rhizomes were consumed by deer during all months from October through April (Parker et al. 1999). The availability of rhizomes, however, is temperature

dependent – even during snow-free winter periods, frozen ground will deter or prevent deer from extracting the rhizomes. Throughout our study, mean maximum and minimum air temperatures by month were lowest during February of both years (-1.3 and -3.0°C) and highest in October (7.4 and 6.1°C), with all months having days when rhizomes were available to deer. Consequently, depending on daily winter temperatures, rhizomes may be an important winter food for Black-tailed Deer throughout the coastal range of southeast Alaska and portions of coastal British Columbia.

Reports of ungulates consuming below-ground biomass are rare (e.g., *Oreamnos americanus*: Hjeljord 1971; Dorcas Gazelles, *Gazella dorcas*: Ward and Saltz 1994), in part because of the difficulty in observing this type of feeding, but our results suggest that even a small loss of "storage" biomass can greatly reduce plant vigour in the following growing season. Other studies have also shown that the effect of removing a portion of the root or rhizome by herbivores can be much more marked than the removal of a portion of the above-ground vegetation. For example, Lesser Snow Geese (*Chen caerulescens*) grubbing for roots and rhizomes of salt-marsh graminoids (e.g., Belanger et al. 1990), especially in combination with increased evaporation rates from the disturbed

TABLE 1. Results of ANOVAs comparing the vegetative regrowth of the entire *Dryopteris* fern, the fiddlehead and frond in May (df = 4,111), June (df = 4,117), July (df = 4,117) and September (df = 4,108) following browsing of the rhizome by Black-tailed Deer during the previous winter. p values represent the probability of the overall effect of rhizome removal when all treatments (0%, 1-25%, 26-50%, 51-75% and 76-99%) were compared. In all cases for which we obtained a significant ANOVA, only one treatment (specified in the "Sig. Treat." column below) differed significantly from all other treatments by Tukey's range test.

Plant Part	Month											
	May			June			July			September		
	p	F	Sig. Treat.	p	F	Sig. Treat.	p	F	Sig. Treat.	p	F	Sig. Treat.
Entire Fern	0.001	19.91	0%	0.001	28.57	0%	0.001	37.16	0%	0.001	25.56	0%
Fiddlehead	0.001	10.74	0%	0.765	0.46	—	0.951	0.17	—	0.001	14.14	25%
Frond	0.001	6.48	0%	0.001	27.28	0%	0.001	36.91	0%	0.001	26.12	0%

sediments, can result in increased desertification (Srivastava and Jefferies 1996). Further, biological control of Purple Loosestrife (*Lythrum salicaria*) is achieved by a Weevil that attacks the plant's root system (Blossey 1993).

The control plants that we used in this experiment were growing on a different island. Although the fronds of unbrowsed plants were similar in size on both islands, they may not have been growing under identical microclimatic conditions. Even if these differences existed, however, they would be very small when compared to the marked response of the ferns to partial rhizome consumption (Figure 2). Even the removal of small amounts of rhizomes appears to delay plant growth, which may be targeted by deer later in the growing season. Although we were unable to monitor these plants over several years to examine long-term effects of this herbivory, we suspect that continued foraging by deer would greatly reduce any recovery by these ferns. When sheep (*Ovis aries*) were excluded from pasture they had occupied for a long time, however, one of the effects was the emergence of *Dryopteris dilatata* on the grassland (Hill et al. 1992). *Dryopteris*, therefore, may be able to recover when deer densities are low or in years when other foods or winter conditions decrease foraging. We believe that the relative abundance of *Dryopteris* on a particular site may be indicative of deer use. Biologists and forest managers using forest classification systems should recognize that the presence or absence of *Dryopteris* may be less of an indicator of overall habitat quality and more of an index to previous winter foraging by Black-tailed Deer.

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Small Mammal Abundance and Community Composition in Prince Edward Island National Park

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Small mammal communities were studied in eight vegetation types of the Prince Edward Island National Park, Prince Edward Island. Ten species were trapped. Shannon-Weiner index of diversity was high in Red Pine plantations (1.33 and 1.55) and a bog (1.47), and low for opened habitats such as a dune (0.19), and a freshwater wetland (0.60). Evenness was highest in Red Pine plantations, and lowest for wooded habitats including an Acadian forest. Relative abundance varied among species and habitats. Although the most widespread species was *Sorex cinereus*, the greatest abundance (16.8 individuals/100 trapnights) was reached by *Tamias striatus* in the Acadian forest. We hypothesized that natural factors such as predation and population fluctuations may explain the levels of abundance of small mammal species in the park. In some areas, visitor accommodations and current human activity may have also modified the dynamics of some species.

Key Words: Small mammals, rodents, shrews, diversity, community composition, National Park, Prince Edward Island.

Prince Edward Island is situated in the Gulf of St. Lawrence, and covers an area of approximately 5660 km² (Weighs 1995). Its original vegetation was Acadian forest characterized by the presence of Sugar Maple (*Acer saccharum*), Red Maple (*Acer rubrum*), and Trembling Aspen (*Populus tremuloides*) (Farrar 1995). The forest ground vegetation included a great diversity of herbaceous vegetation such as Bunchberry (*Clintonia borealis*) and Bluebead Lily (*Cornus canadensis*), as well as mosses (Clark 1959). When settlers arrived in the early eighteenth century, they cleared the land for farming, and later timber was harvested for lumber and shipbuilding (Sharpe 1976). Most of the original forest was eventually cut, and only scattered fragments were left (Bateman and Prescott 1984). Although agriculture continues to predominate on the island, many old fields have now regenerated into young forests. Other habitat types, such as wetlands and sand dunes, have also become isolated. (Bateman and Prescott 1984).

Information on the biology and ecology of the small mammal species of the island is limited. Except for the study conducted by Cameron (1956), the few attempts to study small mammals on the island have been confined to inventories conducted by Parks Canada in the Prince Edward Island National Park (Bateman and Prescott 1984; Corbett 1986; Prescott and Ouellette 1980). Based on these studies, fifteen species are believed to occur in the park. These include five insectivore species (Bateman and Prescott 1984): Masked Shrew (*Sorex cinereus*), Smoky Shrew (*Sorex fumeus*), Common Water Shrew, (*Sorex palustris*), Pygmy Shrew (*Sorex hoyi*), and Northern Short-tailed Shrew

(*Blarina brevicauda*). Only the Masked Shrew is classified as being abundant, the other three are considered to be rare, while the presence in the park of the fourth, the Smoky Shrew, is uncertain. Among rodents, only the Meadow Vole (*Microtus pennsylvanicus*) and the Meadow Jumping Mouse (*Zapus hudsonius*) are considered to be abundant within the boundaries of the park (Bateman and Prescott 1984). The Northern Flying Squirrel (*Glaucomys sabrinus*), Woodland Jumping Mouse (*Napaeozapus insignis*), Norway Rat (*Rattus norvegicus*), and House Mouse (*Mus musculus*), are all classified as being rare species. The status of the Eastern Chipmunk (*Tamias striatus*), Deer Mouse (*Peromyscus maniculatus*), and the Southern Red-backed Vole (*Clethrionomys gapperi*) is unknown (Bateman and Prescott 1984). The objective of this study was to provide quantitative information on the abundance and diversity of small mammals in various vegetation types of the Prince Edward Island National Park.

Study Sites

The study was conducted in the Prince Edward Island National Park (46°23'42" to 46°30'48"N; 62°57'50" to 63°28'55"W) from June to August 1997. This park was formed in 1937, and includes private homes and tourist accommodations within the park boundaries (Keith 1996). It is a narrow strip of land which extends about 40 km along the island's north shore, but encompasses an area of only 18.2 km² (Bateman and Prescott 1984). Wetland habitats cover about 22% of the park area whereas dune habitats cover about 21% (P. Ayles, personal communication). Wooded habitats including softwood, hardwood, and mixed forests represent

approximately 25% of the park's surface. Topography of the park is relatively flat, the highest elevation being about 60 m (Bateman and Prescott 1984). Prince Edward Island has a humid continental climate with an average monthly summer temperature varying from 10°C to 14°C (Bateman and Prescott 1984). However, during the summer of 1997, the average monthly temperature in the study area was 13.7°C in June, 19.6°C in July, and 17.9°C in August (Recorded by Parks Canada: Stanhope Weather Station). Annual precipitation on the island varies generally from 890 mm to 1140 mm (Bateman and Prescott 1984). Total precipitation from June to August 1997 was 140.3 mm (Recorded by Parks Canada: Stanhope Weather Station).

The various habitat types found within the park boundaries have been described in detail by Anderson (1993) and Bateman and Prescott (1984). Eight vegetation types, representing the major plant communities of the Prince Edward Island National Park were sampled for small mammal abundance and composition. These vegetation types included a sand dune, two Red Pine (*Pinus resinosa*) plantations, an abandoned agricultural field, a freshwater wetland, an Acadian forest, a hardwood forest, a bog, and a mixed forest. The Acadian forest habitat (46°29'02"N, 63°29'58"W) sampled in this study is not part of the original Acadian forest, but is a mature stand containing a similar species composition (Farrar 1995). This forest covers an area of 5.6 ha, and is surrounded by agricultural fields and a walking trail which is regularly used by bicycles and farm vehicles. In this habitat, ground vegetation is dominated by Bunchberry, Blue-bead Lily, and mosses. The hardwood stand (46°29'32"N, 63°23'30"W) covers an area of 3.6 ha and is primarily composed of mature Red Maple trees. It is bordered on one side by private property and by an amusement park on the other side. Ground vegetation in this habitat includes White Violet (*Viola palensis*), Speckled Alder (*Alnus millifolium*), and grasses. Red Pine plantation A (46°24'30"N, 63°04'22"W) was planted approximately 50 years ago (P. McCabe, personal communication). Ground vegetation is sparse and limited to a few acid tolerant shade-dwelling species such as Bunchberry and Blue-bead Lily. Red Pine plantation A covered an area of approximately 1 ha and was bisected by a trail only used for walking and cycling.

The bog (≈0.8 ha), the mixed forest (≈0.3 ha) and the Red Pine plantation B (≈1.1 ha) were all located in the same area. The bog (46°24'36"N, 63°04'08"W) was adjacent to the mixed forest (46°24'34"N, 63°04'06"W), which was itself adjacent to the Red Pine plantation B (46°24'33"N, 63°04'04"W). The bog was characterized by the presence of plants such as sphagnum (*Sphagnum* sp.), Labrador Tea (*Ledum groenlandicum*), and

Small Cranberry (*Vaccinium oxycoccus*). Some Gray Birches (*Betula populifolia*) and White Spruces (*Picea glauca*) were also present. The mixed forest included species such as White Spruce, Birches, and Balsam Fir, with the latter being the most abundant species. Similar to Red Pine plantation A, Red Pine plantation B was also planted about 50 years ago (P. McCabe, personal communication). Aside from the presence of some Hawkweed (*Hieracium* sp.) and Starflowers (*Trientalis borealis*), living ground cover in Red Pine plantation B was sparse, although more abundant than in Red Pine plantation A. These three habitats were bordered on one side by an unpaved road (≈5 m away), and by a highway (≈5 m away) on the other side.

The dune habitat (46°24'56"N, 63°03'57"W) encompassed an area of about 1.1 ha, and was located at approximately 20 m from a small trail leading to a beach. The sand dune was colonized almost entirely by Bayberry (*Myrica pensylvanica*). The freshwater wetland (46°25'01"N, 63°05'28"W) of about 2 ha occurred at the outlet of a large pond, and was characterized by Sweet Gale (*Myrica gale*), Meadow-sweet (*Spiraea latifolia*), and Wild Rose (*Rosa virginiana*). The agricultural field (46°29'46"N, 63°24'57"W) was abandoned approximately 20 years ago (P. McCabe, personal communication). A few old apple trees (*Malus* spp.) remain, and some White Spruce trees have colonized the area, but shrubs such as roses (*Rosa* spp.) predominate. The old field covers an area of 1.4 ha, and is situated at the edge of a popular hiking and cycling trail.

Methods

Small mammals were live-trapped in rectangular grids that varied according to the size of the sampled area in order to reduce problems related to over- and undersampling (Sutherland 1996). Small grids were used for three sites (bog, mixed-forest, and Red Pine plantation B), while medium-sized grids were used for six sites (wetland, dune, old agricultural field, Red Pine plantation A, Acadian forest, and hardwood forest). Grids were set up in each site in order to sample the small mammal community within the vegetation types and the species living on the edges. We varied the space between trap stations according to the vegetation type (Gurnell and Flowerdew 1990). In the wetland, dune, and old agricultural field, each grid contained 40 Sherman traps, spaced at 5 m intervals in an 5 × 8 pattern. Grids used in the Red Pine plantation A, Acadian forest, and the hardwood forest also contained 40 Sherman live traps in a 5 × 8 pattern, however, trap stations were spaced at 10 m intervals. A pattern of 4 × 8 was used for the bog, while a 3 × 8 pattern was used in both the mixed forest and Red Pine plantation B. Trap stations were spaced at 10 m intervals. Because

of other ongoing research at the time, half of the trap stations used in each one of these three habitats included two Sherman traps. Thus, grids contained 48 traps in the bog and 36 traps in both the mixed forest and the Red Pine plantation B. All Sherman traps used in this study were large (50 × 62 × 165 mm). Pitfall traps were located between Sherman trap stations. They were made of plastic bottles 15 cm in diameter, and placed into holes 40 cm deep. Therefore, the number of pitfall traps used in each habitat represented about 8% of the total number of Sherman trap stations. All pitfall traps were baited and provided with water drainage holes. In all habitats, both Sherman and pitfall traps were checked at approximately eight hour intervals during four consecutive days. Traps were baited as necessary with a mixture of peanut butter, rolled oats, fruit, bacon, and vanilla. Captured animals were identified, weighed, marked with numbered ear tags, and released. Sex, reproductive condition, and injuries were also noted. Traps that had been robbed or moved but remained functional were considered to have been 50% effective. Traps that were closed or moved without remaining functional were considered to have been 100 % ineffective.

Due to unequal trapping efforts and disturbance problems, the relative abundance of each population was expressed as percentage capture rate (captures / 100 trapnights). We calculated the Shannon-Weiner diversity index ($H' = \sum p_i \ln p_i$; Shannon-Weiner 1949) and evenness ($E = H'/H_{\max}$, where $H_{\max} = \ln S$; Smith 1996) for communities of small mammals in each habitat. The Jaccard's index of community similarity was used to compare community structure of small mammals between habitats (Smith 1996). Kruskal-Wallis and Mann-Whitney U tests were used to compare Jaccard's index values between different vegetation types. A subjective index of habitat complexity based on species richness in terms of both plants and trees was calculated for each study site (Table 1).

Results

A total of 175 individuals of 10 species were caught (Table 2). Trap nights ranged from 161 to 670 per habitat, with 3184 for the entire study. Trapping success with Sherman traps varied from 0.9% to 18.6%, with an overall trapping success of 5.3% for the study (Table 2). A higher number of animals were caught in Sherman traps (168 captures) than in pitfall traps (7 captures). Pitfall traps only captured one Masked Shrew in four different vegetation types (Red Pine Plantation A, wetland, dune, and mixed forest), two Meadow Jumping Mice in the wetland, and one Southern Red-backed Vole in the bog.

Species richness ranged from two to six species per habitat (Table 2). Diversity of small mammals was greater in wooded habitats than in open habitats (U-test; $p < 0.05$). The highest small mammal diversity was found in the bog (1.47) and Red Pine plantations (1.33 and 1.55). The abandoned agricultural field was the poorest community in terms of both diversity and species richness (Table 2). Evenness also varied among habitats (Table 2). Small mammal assemblages in both plantations and the wetland were the most even, whereas those in the Acadian forest and the hardwood forest were the least even. However, no significant Spearman rank correlation was found between evenness and species diversity ($p > 0.05$).

The composition of the small mammal community found in each habitat varied widely (Table 3). Dune and wetland habitats supported identical small mammal assemblages. Red Pine plantation B showed a strong similarity to the hardwood forest, whereas Red Pine plantation A was more similar to the bog than to the Red Pine plantation B. Communities of small mammals occupying the old agriculture field and the Acadian forest were the most dissimilar to those in other habitats (average Jaccard's index were 0.12 and 0.14 respectively). However, no significant differences were found in Jaccard's index values between study sites (Kruskal-Wallis; $p > 0.05$). This

TABLE 1. Habitat complexity and species richness in terms of both trees and plants of each study site in the Prince Edward Island National Park.

Vegetation Type	Tree Species Richness	Plant Species Richness	Abundant Plant Species	Common Plant Species	Complexity Index ¹
Wetland	0	5	1	2	1
Dune	0	6	1	1	2
Agricultural field	3	6	4	1	3
Red Pine plantation A	3	4	1	2	4
Bog	2	7	3	1	5
Hardwood forest	4	9	1	3	6
Acadian forest	5	7	2	1	7
Red Pine plantation B	5	14	2	2	8
Mixed forest	13	9	3	1	9

¹Study sites are ranked by increasing complexity.

TABLE 2. Summary of the number of captures in in Sherman live traps, Shannon-Weiner index of diversity and evenness for various vegetation types in in the Prince Edward Island National Park.

Habitat	Total trap nights	Captures (day)	Captures (night)	Total Success (%)	Species richness	Species diversity	Evenness
Acadian forest	161	29	1	18.6	3	0.55	0.58
Hardwood forest	238	18	8	10.9	4	0.82	0.57
Red Pine plantation A	271	2	6	3.0	4	1.33	0.95
Red Pine plantation B	453	6	3	2.0	5	1.55	0.94
Mixed forest	467	26	6	6.9	5	1.34	0.76
Bog	670	23	10	4.9	6	1.47	0.72
Dune	357	7	17	6.7	2	0.19	0.61
Wetland	351	3	1	1.1	2	0.60	0.91
Agricultural field	216	2	0	0.9	1	—	—

indicated that differences in small mammals community composition between study sites were not significant.

Eight species of rodents in three families and two species of insectivores were captured (Table 4). The most frequently captured species was the Eastern Chipmunk (32.6 % of all captures), followed by the Red-backed Vole (18.9 % of all captures), and the Meadow Jumping Mouse (16% of all captures). Six species occurred in only one habitat (bog), and except for one species (Southern Red-backed Vole) all had relatively low abundance. Most individuals (70%) captured in both plantations were trapped along the edges. The Northern Short-tailed Shrew was the only species captured in only one habitat (Acadian forest). The highest abundance for a species was that of the Eastern Chipmunk in the Acadian forest (16.8/100 trapnights). Except for two individuals captured in the abandoned agricultural field site, the Eastern Chipmunk was exclusively captured in wooded habitats (Table 4). Capture rate of Meadow Jumping Mice in the dune habitat was also high

(6.4/100 trapnights). Although the Masked Shrew was the most widespread species, it was not particularly abundant in any of the five vegetation types in which it was found.

Discussion

Our findings show that both species diversity and relative abundance varied among vegetation types within the Prince Edward Island National Park, with wooded habitats supporting the highest diversity of small mammal species.

Several studies have reported differences in terms of trapping efficiency between Sherman and pitfall traps (e.g., Dowler et al. 1985; Boonstra and Rodd 1983;). Our results showed that Sherman traps were more efficient than pitfalls in most vegetation types, capturing not only a higher number of individuals, but also a wider variety of small mammal species. The only habitat where pitfall traps were as efficient as Sherman traps was the wetland. Drowning occasionally occurred during periods of heavy rain in other habitats, but water seeped continually into most of the pitfall traps set in the wet-

TABLE 3. Jaccard's¹ community similarity index for various vegetation types in the Prince Edward Island National Park.

Habitat	Acadian forest	Hardwood forest	Red Pine plantation A	Red Pine plantation B	Mixed forest	Bog	Dune	Wetland	Agricultural field
Acadian forest	—								
Hardwood forest	0.17	—							
Red Pine plantation A	0.0	0.33	—						
Red Pine plantation B	0.14	0.80	0.50	—					
Mixed forest	0.33	0.13	0.29	0.25	—				
Bog	0.13	0.25	0.67	0.38	0.57	—			
Dune	0.0	0.0	0.20	0.17	0.17	0.14	—		
Wetland	0.0	0.0	0.20	0.17	0.17	0.14	1.0	—	
Agricultural field	0.33	0.25	0.0	0.20	0.20	0.0	0.0	0.0	—

¹ Jaccard's index of community similarity = $\frac{C}{S_1 + S_2 + C}$

Where:
C= number of species common to both habitats
S₁= number of species in habitat 1
S₂= number of species in habitat 2

TABLE 4. Percentage of capture rates (captures/ 100 trapnights) of small mammals species in various vegetation types in the Prince Edward Island National Park.

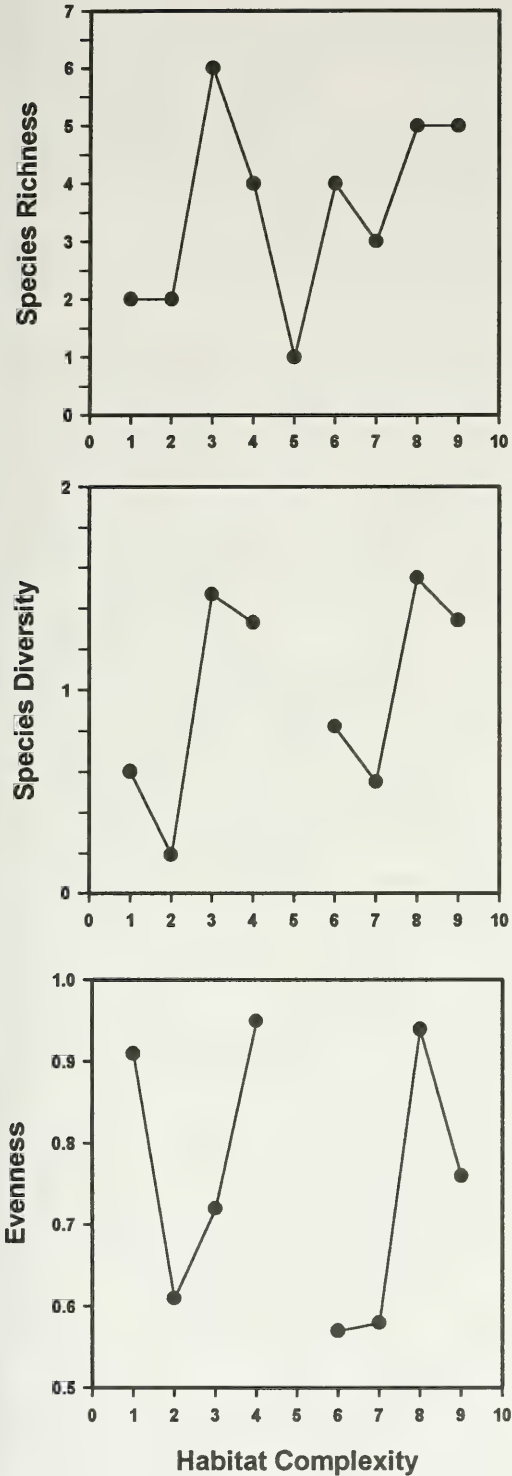
Specie*	Acadian forest	Hardwood forest	Red Pine plantation A	Wetland	Dune	Agricultural Field	Bog	Mixed forest	Red Pine plantation B
<i>Blarina brevicauda</i>	1.2								
<i>Clethrionomys gapperi</i>	0.6						2.1	3.6	
<i>Glaucomys sabrinus</i>		0.4							0.4
<i>Microtus pennsylvanicus</i>							0.9	0.2	
<i>Napaeozapus insignis</i>		0.4	0.4				0.9		0.7
<i>Peromyscus maniculatus</i>			1.5				0.1	1.3	
<i>Sorex cinereus</i>			0.4	0.3	0.3		0.7	0.6	0.2
<i>Tamias striatus</i>	16.8	8.8				0.9		1.1	0.4
<i>Tamiasciurus hudsonicus</i>		1.3	0.7				0.1		0.2
<i>Zapus hudsonius</i>				0.9	6.4				

land and most individuals in them were dead. This concurs with Kirkland et al.'s (1997) work who suggested that water-filled pitfall traps are more effective since animals have no chance to escape. Moreover, the inefficiency of dry pitfall traps in most sites may partially explain why so few shrews were captured during this study. While pitfall traps are known for being particularly efficient in capturing species weighing less than 10 g (Mengak and Guynn 1987; Briese and Smith 1974), shrews generally represent a small proportion of the samples collected with Sherman traps (G. L. Kirkland, personal communication). Because of this our study may underestimate the diversity and relative abundance of shrews.

Increased habitat complexity generally leads to increased abundance, diversity and richness of wildlife species within that habitat (Canova 1992; Parker 1989). Results of our study suggest that small mammal communities in the Prince Edward Island National Park may be affected by both vegetation type and habitat complexity (Figure 1). Although Red Pine plantations showed high levels of species diversity, relative abundance of small mammals occupying these habitats was generally low, especially in Red Pine plantation A. Several studies have shown that small mammal diversity is positively correlated with ground cover (Abramsky 1988; Abramsky and Rosenzweig 1984; Kerley 1992; Owen 1988). Ground cover in Red Pine plantation A was limited to some herbaceous plants and Red Pine needles. Furthermore, because most individuals captured in both plantations were trapped along the edges, it is possible that some of the species captured in this vegetation type may have lived primarily in adjacent habitats. This may explain why the area encompassing the bog, the mixed forest, and Red Pined plantation B showed so little difference in terms of community composition. It is possible that the mixed forest partially supported the populations of small mammal species found in both bog and Red Pine plantation B.

The harshness of the dune probably contributed to the high abundance and low diversity of small mammals found in that habitat (Zukal 1993). Aside from the abundant Meadow Jumping Mouse, only the Masked Shrew and one observed Red Squirrel (*Tamiasciurus hudsonicus*) inhabited the dune, and both in a low abundance. The Masked Shrew is usually found in moist habitats while the Red Squirrel is a forest-dweller (Cameron 1956), so the dune may be at the limit of suitable habitat for these species. Red Squirrels are strongly associated with conifer trees for foraging (Riege 1991; Lair 1985). Since only a single Red Squirrel was observed twice during the trapping period, it is probable that this individual was only a transient living primarily in adjacent habitats.

The Short-tailed Shrew is usually found in mature mixed or deciduous forests (Bateman and Prescott 1984; Clough 1987; Getz 1989). In this study, however, the Short-tailed Shrew was only captured in the Acadian forest. This result concurs with Bateman and Prescott's (1984) suggestion that the Short-tailed Shrew is a rare species in the Prince Edward Island National Park. It is also possible that because the species is reaching its northern distributional limits in the Maritimes, population abundance is low. Several studies have found that population abundance varies over the range of distribution of species, with the average abundance decreasing from the center of the range toward the margins (e.g., Hengeveld and Haeck 1982; Brown 1984). Support for this hypothesis also comes from Kirkland and Schmidt (1982) who found the Short-tailed Shrew to be widespread but never abundant in Nova Scotia and New Brunswick forests. Another possible explanation is that nocturnal trap disturbance can explain the low number of Short-tailed Shrews captured during this study. It is possible that although present in other habitats, it was not detected because of the inefficiency of the nocturnal trapping. The Deer Mouse is a generalist species (Boone and Keller 1993; Hamilton 1941) that has been



found to occupy a wide range of habitats (e.g., Galindo and Krebs 1985). It is often more abundant in deciduous forests (Clough 1987; Stickel and Warbach 1960), but in this study it was captured in Red Pine plantation A, the bog, and the mixed forest. In one study conducted outside the boundaries of the national park (Herman and Scott 1984), it was reported that although present in some natural habitats, the Deer Mouse has consistently low abundance on Prince Edward Island. This may also account for the small number of individuals captured in the park. The two introduced species (Norway Rat and House Mouse) were not captured or observed during this study. These species are usually commensal with humans, or occur in anthropogenic habitats such as agricultural fields which were not examined in this study.

Three species of the family Sciuridae were captured or observed in the park. Among them, the most abundant was the Eastern Chipmunk which except for Red Pine plantation A, was captured in all of the wooded habitats examined during this study. This finding is not consistent with previous studies where it was suggested that the Eastern Chipmunk was an uncommon species in Prince Edward Island National Park (Bateman and Prescott 1984; Cameron 1956). In contrast, our findings not only show that the Eastern Chipmunk is a widespread species, but they also demonstrate that it is a numerically dominant species in both the Acadian forest and the hardwood forest. Failure to capture Eastern Chipmunks during previous studies (e.g. Bateman and Prescott 1984) may be attributed to the trapping design or to fluctuations over time in population levels. Although Northern Flying Squirrels were only captured in the hardwood forest and the Red Pine plantation B, a few individuals were also observed in all the other wooded habitats. Prior to this study there was only one record of a Northern Flying Squirrel from the park (Bateman and Prescott 1984). Northern Flying Squirrels are nocturnal animals that generally prefer mature forests (Witt 1992). This type of habitat is limited within the park. It is also possible that with a higher trapping efficiency at night in wooded habitats, more individuals could be captured (Cameron 1956). The use of traps located on trees would also contribute to provide a more robust estimate of the relative abundance of this arboreal species.

FIGURE 1. Relationship between habitat complexity and species richness, species diversity and evenness of small mammals in the Prince Edward Island National Park. Species diversity was calculated using the Shannon-Weiner diversity index ($H' = \sum p_i \ln p_i$). Evenness was assessed using the following formula: $E = H'/H_{\max}$, where $H_{\max} = \ln S$. Habitat complexity is based on species richness in terms of both plants and trees (see Table 1).

Few studies have been conducted on the small mammals of the Prince Edward Island National Park or elsewhere in the province. Of the fifteen species expected to occur in the park (Bateman and Prescott 1984), only ten were captured or observed during this study. This low species diversity may be due not only to the short duration of this study, but also to disturbances by Raccoons (*Procyon lotor*) at night. Observations indicated that Raccoons visited the traps early in the evening. Bait was stolen without springing the trap, and other traps were closed and moved by Raccoons several meters away from the trap station. It is also possible that some of the species not captured or observed during this study may have been at a low point in abundance; fluctuations in numbers are common in many small mammal species (e.g., Fryxell et al. 1998; Krebs 1996). For example, even though Bateman and Prescott (1984) classified the American Red Squirrel as being common in the park, they reported that they were not abundant in 1978 and 1979. Alternatively, it is possible that species not captured during this study have simply diminished without recovery during the last 20 years. Herman and Scott (1984) suggested that small mammal population dynamics on Prince Edward Island may be very different from elsewhere in the Maritimes, and that abundances of Deer Mouse, Red-backed Vole, and Woodland Jumping Mouse may be continually particularly low. Our findings might be an indication that this may also be true for other small mammal species occupying the various habitats of the Prince Edward Island National Park.

Little is known about the effects of predators such as Raccoons or Red Foxes (*Vulpes vulpes*) on the small mammals of the park. Frequent observations of Raccoons within or near the study sites suggest that they may have experienced an increase in numbers in the last 10 to 15 years. The increased risk of predation may affect the foraging behavior of small mammal species (e.g., Lima and Valone 1986; Otter 1994), and consequently their distribution and population dynamics.

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Nesting Biology of the Tennessee Warbler, *Vermivora peregrina*, in northern Ontario

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Fourteen Tennessee Warbler, *Vermivora peregrina*, nests were monitored during the 1994 breeding season near Longlac, Ontario. Videocameras were used to record various aspects of parental care. In our study area, Tennessee Warblers nested in relatively dry, open areas. The edges of old logging roads and small clearings were favoured nesting locations. The nests were well concealed. Cover was provided by a variety of ground plants, in particular mosses, grasses, Bunchberry and Large-leaved Aster. The median clutch size of 11 nests was 6 eggs (range 5 to 7). Hatching success was 94%. The median brood size of 14 nests was 6 nestlings (range 4 to 7). The interval from the laying of the last egg to the hatching of the first nestling was 7–8 days. This is exceptionally short compared to that of other warbler species. A short incubation period may be an adaptation that allows the species to take maximum advantage of a pulsed food supply (i.e., Spruce Budworm) for nestling growth and development. The Mayfield estimate of nest success for Tennessee Warblers in this study (73.3%) was high compared to other ground-nesting songbird species. Male Tennessee Warblers provisioned their nestlings at higher rates than did their mates, especially during the first few days of nestling life. Feeding rates increased with increasing nestling age and brood size. Lepidoptera larvae and pupae were the most common food items in the diets of nestlings.

Key Words: Tennessee Warbler, *Vermivora peregrina*, nesting biology, reproduction, breeding success, parental care, northern Ontario.

The Tennessee Warbler, *Vermivora peregrina*, is a common warbler of mixed coniferous-deciduous forests across Canada and into Alaska, with a breeding range extending from central Newfoundland to British Columbia and north to tree-line (Godfrey 1966; Erskine 1977; Welsh 1987). Particularly during periods of Spruce Budworm outbreak, the abundance of Tennessee Warblers in spruce-fir forests can be extremely high (Kendeigh 1947).

Despite its wide distribution and abundance on the breeding grounds, little is known about the nesting biology of this species (Bowditch and Philipp 1916; Bent 1953; Baker 1979; Peck and James 1983). While breeding biology information in general tends to be limited both across species and geographic locations (Martin 1992, 1993), this is particularly true for ground-nesting songbirds such as the Tennessee Warbler. This lack of information has been attributed to a common perception among researchers that ground nests in forests are very difficult and time-consuming to find (Martin and Geupel 1993).

In 1994, a collaborative research project, involving the Canadian Forest Service, the Canadian Wildlife Service, and the University of Toronto, was conducted to determine the effects of spraying with Lepidoptera-specific insecticides on forest songbirds. One aspect of this project was an investigation of the effects of insecticide-induced food reductions on Tennessee Warbler nesting behaviour and repro-

duction (Holmes 1998). In this paper, we present some of the data collected during the course of this study that pertain to the known nesting biology of the Tennessee Warbler.

Study Area and Methods

The study was conducted about 15 km northwest of Longlac, Ontario (49°46'N, 86°33'W) in a mixed forest of Balsam Fir (*Abies balsamea*), White Spruce (*Picea glauca*), Black Spruce (*P. mariana*), Trembling Aspen (*Populus tremuloides*) and White Birch (*Betula papyrifera*). A more complete description of the study site is given in Holmes (1998).

We started searching for nests in the first week of June, following the establishment of Tennessee Warbler territories. Each day for about four weeks, two or more field workers searched for nests after completion of their early morning duties (i.e., foraging observations). Nest searching usually commenced by 09:00 and continued for 3–4 hours. The first nest was found on 8 June and the last nest on 3 July.

We tried a number of different nest-finding methods. Initially, we looked for male Tennessee Warblers that were singing on territory. We then chose a location on the edge of an open area offering a good view of the territory and watched for a nest-building female. If a female was observed carrying nesting material, we watched her from a distance and

ultimately followed her to the nest. If no female was seen, we moved to another location in the territory.

We also watched for sexual chases, as we found that some females followed the chase with a nest visit. Chases often commenced at tree or shrub level, and were characterized by very short, rapid flights and hops by both adults from one vegetation layer to another, moving progressively lower until eventually dropping to the ground. Some observed chases lasted for more than 15 minutes and were repeated a number of times.

However, the most effective nest-finding method involved both aural and visual tracking of the female. We found that female Tennessee Warblers emitted a distinct and constant "tsit" call in the vicinity of the nest. Similar call-notes are common to many species of Parulidae and occur when the female is just about to leave, or is off, the nest (Martin and Geupel 1993). Once off the nest, the females usually remained close-by, making it a relatively simple matter to locate the general nesting location. We then observed the female from a distance, watching her visit the nest until we were confident of its exact location. This method was most effective during the egg-laying and incubation stages. After hatch, the females called far less frequently and were much more difficult to locate and track.

We also located a number of nests when observers who were tracking males during early morning foraging observations accidentally flushed females from their nests. These females were invariably within 50 m of the male's singing location.

After a four-week period of intensive searching, 14 active nests were located. Of these, two nests were found prior to egg laying, two had incomplete clutches, seven had complete clutches and were being incubated, and three had nestlings.

Two methods were used to monitor nests. During the egg-laying and incubation stages, nests were visited daily and the eggs were counted. On hatching, each nestling was weighed to the nearest 0.1 g on a Pesola® balance and its left tarsus was measured to the nearest 0.1 mm with dividers and a ruler. In addition, each newly hatched nestling was marked with a unique combination of marks on the wings and/or legs using a Sanford® non-toxic, permanent marker. We replaced these marks with coloured leg bands when the nestlings were 3-5 days old. During the nestling stage, the nests were visited less frequently, usually every second day, to reduce disturbance. Final measurements were taken when the nestlings were 5-6 days old. We avoided handling older nestlings, as they appeared highly sensitive to disturbance.

On alternate days (i.e., days that nestlings were not measured), nests were videotaped using a Sony® CCD-TR30 Video 8 Handycam® to gather information on parental feeding rates and nestling diets. The

tripod-mounted cameras were placed 1.5-2 m away from the nests. To make the cameras less obvious to parents and potential predators, they were swathed in camouflage cloth and concealed behind natural cover. Although we did not specifically test for reactions to the cameras, the parents appeared to be largely unconcerned by their presence. In some cases, females remained on their nests during camera set-up or returned to their nests within seconds of the camera team's departure. Videotaping was conducted daily from 29 June to 6 July, usually between 08:00 and 11:00 (early sessions) and between 11:00 and 14:00 (late sessions). With three cameras, it was possible to videotape six nests per day. Videotaping sessions at each nest were alternated between early and late time periods, with 2-4 days (median 2 days) between taping sessions for any particular nest. Sessions usually lasted about 2 hours (maximum tape length), although some were shorter due to technical difficulties. Over the eight-day study period, 36 sessions were taped for a total of 69.7 hours.

Videotapes were played back through the camera on a Panasonic® Color Video Monitor, Model Number CT-1930VC. Feeding trips were counted and times between visits to the nest were measured. Behaviours of parents at the nest were classified (e.g., brooding, perching, nest cleaning, feeding nestlings, etc.), timed and counted. Prey items brought back to nestlings were identified, counted and their size estimated relative to the adult beak length (10.5 mm; Godfrey 1966). There is little difference in beak (exposed culmen) length between the sexes in this species (Sealy 1985; Curson et al. 1994).

Of the 14 nests found, eight were located in insecticide-treated blocks (*Bacillus thuringiensis* and MIMIC) and six in a control area. Data were first analyzed to identify differences between blocks. If there were no differences, the data were pooled. Where there were statistically significant differences between blocks (e.g., see brooding in Holmes (1998)), only the control data were used in subsequent analyses.

Most data were analyzed using BMDP/Dynamic Release 7.0 for the PC (BMDP Statistical Software, Inc., Los Angeles, CA). Williams' corrected G-statistic for tests of independence was calculated according to the method of Sokal and Rohlf (1981).

Results

Nest location

In our study area, Tennessee Warblers appeared to select relatively dry, open sites for nesting. Five of the 14 nests were along road edges and another five were in, or on the edges of, small clearings. The remaining four nests were found under a closed canopy (mixed deciduous-coniferous forest dominated by poplar), but in sparsely wooded areas.

TABLE 1. Plants associated with Tennessee Warbler nests. Only species that contributed greater than 1% on average to ground cover within a 1m radius of the nest are included.

	Common name	Scientific name	% Cover	No. sites
Trees	Balsam Fir	<i>Abies balsamea</i>	7.7	9
	willow	<i>Salix</i> sp.	5.1	2
	Speckled Alder	<i>Alnus rugosa</i>	2.4	2
	spruce	<i>Picea</i> sp.	1.3	4
Ground cover	feather mosses	<i>Pleurozium schreberii</i> , <i>Brachythecium</i> sp., <i>Hylocomium splendens</i> and <i>Ptilium crista-castrensis</i>	20.2	12
	Bunchberry	<i>Cornus canadensis</i>		
	grass			
	Large-leaved Aster	<i>Aster macrophyllus</i>		
	Labrador Tea	<i>Ledum groenlandicum</i>	4.6	3
	strawberry	<i>Fragaria</i> sp.	4.4	6
	Prickly Wild Rose	<i>Rosa acicularis</i>	3.7	5
	Naked Mitrewort	<i>Mitella nuda</i>	3.1	5
	raspberry	<i>Rubus</i> sp.	3.1	5
	Wild Sarsaparilla	<i>Aralia nudicaulis</i>	2.4	4
	Sweet Coltsfoot	<i>Petasites palmatus</i>	1.8	8
	Low Sweet Blueberry	<i>Vaccinium angustifolium</i>	1.8	5
	Canada Mayflower	<i>Maianthemum canadense</i>	1.7	4
	horsetail	<i>Equisetum</i> sp.	1.4	3
	Pearly Everlasting	<i>Anaphalis margaritacea</i>	1.1	2
	Twinflower	<i>Linnaea borealis</i>	1.1	4
	goldenrod	<i>Solidago</i> sp.	1.1	4
	sphagnum	<i>Sphagnum</i> sp.	1.1	1

Table 1 summarizes plant cover data for the 14 nests. Most nests were located in areas of dense ground cover. Five nests were found in holes sunk into moss or lichen hummocks. Additional cover was provided by conifer seedlings, dead conifer branches and shrubby plants like Labrador Tea (*Ledum groenlandicum*), as well as mixtures of shorter ground plants such as Bunchberry (*Cornus canadensis*), Large-leaved Aster (*Aster macrophyllus*), grasses and Sweet Coltsfoot (*Petasites palmatus*). Plant cover at two of the sites was less dense than elsewhere, but these nests were still inconspicuous due to the cover afforded by overhanging mosses and dead leaves.

Two other nests were built in holes in the sides of decaying, moss-covered tree stumps. One nest was situated at the bottom of a stump, beneath an overhanging root, concealed primarily by spruce seedlings, Wild Sarsaparilla (*Aralia nudicaulis*), Naked Mitrewort (*Mitella nuda*) and feather moss. The second nest was found midway up a stump, hidden behind a dense curtain of Field Horsetail (*Equisetum arvense*), Wild Rose (*Rosa acicularis*) and grasses.

Two nests were found in long grass and willows (*Salix* sp.) at the edge of a laneway. The nests were totally obscured by the grass, which had settled into thick mats among the sparse willow stalks. Entrance

was possible only through a small hole at the edge of the mat.

Of the remaining five nests, three were located in depressions at the bases of conifer seedlings, surrounded by long grasses, Large-leaved Aster, Common Strawberry (*Fragaria virginiana*) and other plants. One was built in a hole beneath the stem of a Black Spruce sapling, encircled mainly by feather moss, Bunchberry and blueberry (*Vaccinium* sp.). The last was in a depression in the middle of a mat of feather moss, surrounded by willow stalks, Canada Mayflower (*Maianthemum canadense*), Bunchberry, and several other small cover plants.

Nesting chronology, clutch size, brood size

Behaviour of males suggested that Tennessee Warblers were established on territory in the study area by 28 May. The first evidence of nest building was seen on 8 June, when a partially completed nest was found. The first egg was laid in this nest on 17 June and the last egg on 22 June. The last eggs were laid in two other nests on 20 June and 21 June.

Clutch size could be determined in 11 of the 14 nests. Two nests had a clutch size of 5 eggs, six nests contained 6 eggs and three nests contained 7 eggs (median clutch size = 6 eggs). Hatch occurred between 27 June and 1 July (median hatch date 29 June). The overall hatching success was 94% (median

brood size = 6 nestlings, range 4 to 7). Hatching success was positively correlated with clutch size (87% for 5 egg clutches, 93% for 6 egg clutches and 100% for 7 egg clutches), but this trend was only marginally significant (Spearman rank correlation, $r_s = 0.5897$, $N = 11$, $P = 0.0562$). Hatching occurred over a <24 h period at 4 nests, and over a <48 h period at 6 other nests. In these 10 nests, 46 (81%) of the young hatched in the first 24 h, and 11 (19%) in 24-48 h.

There were enough observations on two nests to estimate the period from the laying of the final egg until the hatching of the first nestling. This was 7 days at one nest (last egg laid on 21 June and nestlings hatched on 28 June) and 8 days at the other (last egg laid on 20 June and nestlings hatched on 28 June). At a third nest, this period was at least 8 days (the date the last egg was laid was not known).

Reproductive success

As stated previously, nestlings were very sensitive to nest disturbance starting at about age 6 days. The young in two nests fledged prematurely when we attempted to measure them at age 7 days. In three other nests, 6-day-old young may have fledged prematurely as a result of activities associated with videotaping. In one case, a nestling was taped as it left the nest, although its three siblings remained. In the other two nests, all of the nestlings were still present at the end of taping, but the nests were empty by the next day.

Because a number of young fledged prematurely in this study, it was not possible to estimate nesting success as the proportion of nesting pairs that successfully fledged at least one offspring. The following data do give some indication of nest mortality/survival rates, however. No nests were depredated/abandoned while they contained eggs ($n = 11$). One nest containing five young was abandoned by the parents when the nestlings were ≤ 1 day old; one nest containing six young was depredated when the nestlings were ≤ 5 days old; one nest survived until the nestlings were at least 5 days old; six nests survived until the nestlings were at least 6 days old; and five nests survived until the nestlings were at least 7 days old.

Mayfield (1975) provided an alternate method of estimating nest success that does not rely on complete records. Assuming a nestling period of 11 days (Rimmer and McFarland 1998) and an incubation period of 8 days (the longer of the two periods we observed), the Mayfield success rate for Tennessee Warbler nests in this study (i.e., the probability that a nest would survive the incubation and nestling periods to produce a fledgling) was 73.3%. This calculation is based on 13 nests and 122 nest-days of exposure.

Parental care

The female parents did most, or all, of the brooding. On two occasions, males exhibited what appeared to be "brooding behaviour", but these events were relatively short in duration (330 and 90

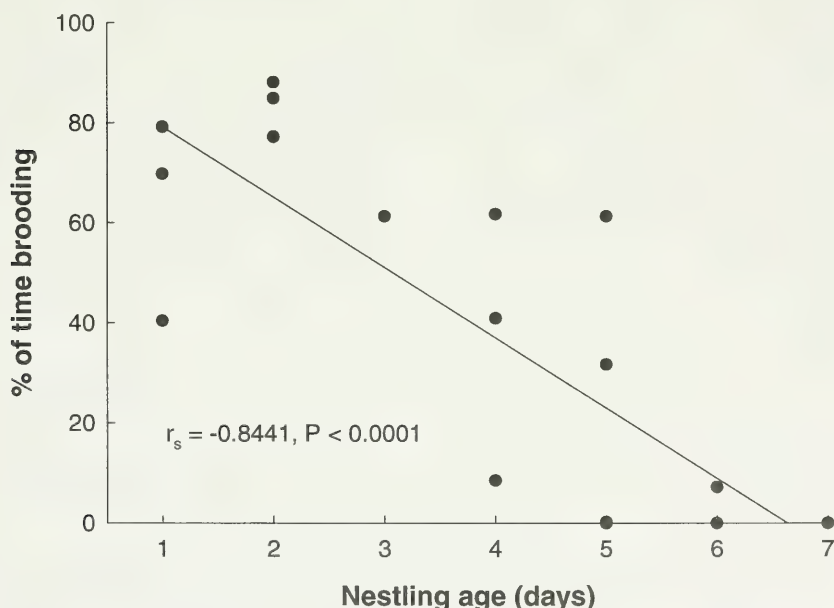


FIGURE 1. Proportion (%) of time spent brooding by adult female Tennessee Warblers during the early nestling period (from age 1 to 7 days).

sec). The mates of these birds brooded for a total of 5396 and 3377 sec, respectively.

Nestlings were brooded up to 6 days of age (Figure 1), but were brooded most when they were 2 days old (83% of the time on average). Brooding declined with increasing nestling age ($r_s = -0.8441$, $N = 20$, $P < 0.0001$), so that 6-day-old nestlings were brooded only about 2% of the time, and 7-day-old nestlings not at all. Time spent brooding was not affected by either brood size ($r_s = -0.1679$, $N = 20$, $P = 0.4791$) or time of day ($r_s = -0.0320$, $N = 20$, $P = 0.8935$).

Nest guarding, nest sanitation and feeding of nestlings by females tended to increase with increasing nestling age, but this trend was not significant (Figure 2; $r_s = 0.067$, $N = 20$, $P = 0.7790$). Males spent little time at the nest (mostly feeding nestlings), regardless of nestling age (Figure 2; $r_s = -0.2467$, $N = 20$, $P = 0.2944$).

Both males and females were observed removing nestling fecal material from the nests. Males removed 81 fecal sacs (54%) and females 70 fecal sacs (46%) during the 69.7 hours of videotaping. Of the 151 fecal sacs removed, 129 were carried away (85%) and 22 (15%) were eaten. The proportion of fecal sacs eaten by males (10 of 81; 12%) and females (12 of 70; 17%) was about the same ($G_{adj} = 0.689$, $P > 0.05$). Fecal sacs were preferentially eaten when nestlings were 1 day old (5 eaten of 6

total; 83%); there was no preference at age 2 days (9 eaten of 18; 50%); and thereafter, fecal sacs were more often carried away (3 eaten of 14 at age 3 days (21%); 2 of 28 at age 4 days (8%), 2 of 29 at age 5 days (7%), 1 of 44 at age 6 days (2%) and 0 of 9 at age 7 days). This trend was highly significant (test for linear trend, $\chi^2 = 39.299$, $df = 1$, $P < 0.0001$).

Males fed their brooding mates on 7 of 22 trips to the nest (32%) when nestlings were 1 day old (3 of 3 males). This was reduced to 8 of 40 trips (20%) when nestlings were 2 days old (3 of 6 males), and to 4 of 25 trips (16%) when nestlings were 3 days old (1 of 4 males). Males did not feed their mates at the nest (0 of 194 trips) between nestling ages 4 to 7 days. This trend was highly significant (test for linear trend, $\chi^2 = 49.278$, $df = 1$, $P < 0.0001$).

For the first 3 days of nestling life, males made more feeding trips to the nest than did their mates (Table 2). This difference was greatest for 1-day-old nestlings, but was significant only for 2-day-olds (Mann-Whitney rank-sum test, $P = 0.0374$). Males also delivered more food to their nestlings (Table 2). This difference was significant for 2-day-olds (Mann-Whitney, $P = 0.0163$) and for all ages combined (Mann-Whitney, $P = 0.0368$). Overall, males provisioned nestlings with about 50% more food than did their mates.

There was no significant difference between males and females in the number of food items brought to

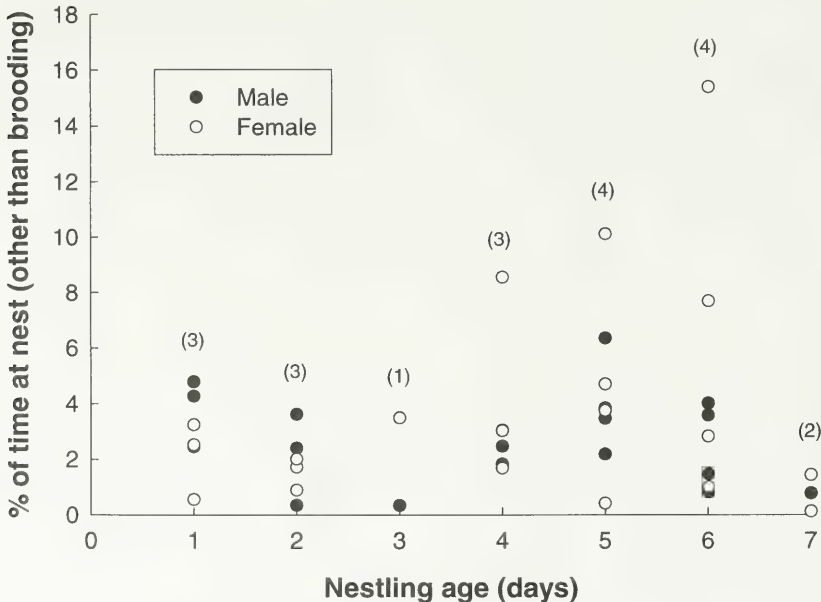


FIGURE 2. Proportion (%) of time spent at the nest (other than brooding) by adult Tennessee Warblers during the early nestling period (from age 1 to 7 days). Only nests where both parents were in attendance are included. Numbers in brackets refer to the number of pairs observed at that nestling age.

TABLE 2. Feeding rates and biomass of food delivered to nestlings (mean \pm standard error) by male and female Tennessee Warblers at various nestling ages. Values followed by the same letter are significantly different at $P < 0.05$ (Mann-Whitney rank-sum test).

Nestling age (d)	feedings/h			mg/h		
	Male	Female	δ/f	Male	Female	δ/f
1	3.55 \pm 1.74	0.98 \pm 0.70	3.62	46.1 \pm 21.7	10.0 \pm 9.5	4.61
2	3.78 \pm 0.68a	1.57 \pm 0.55a	2.41	55.9 \pm 6.7b	15.1 \pm 8.0b	3.70
3	3.17 \pm 0.81	2.77 \pm 0.79	1.14	65.5 \pm 26.4	31.1 \pm 18.7	2.11
4	4.83 \pm 0.27	4.92 \pm 0.67	0.98	90.3 \pm 24.4	50.9 \pm 9.8	1.77
5	4.33 \pm 0.64	5.32 \pm 1.02	0.81	54.9 \pm 7.1	72.6 \pm 4.6	0.76
6	5.18 \pm 0.82	5.55 \pm 0.84	0.93	65.7 \pm 15.7	46.9 \pm 8.1	1.40
1-6	4.27 \pm 0.34	3.84 \pm 0.45	1.11	63.5 \pm 6.8c	41.1 \pm 5.2c	1.55

the nest per feeding trip (Mann-Whitney, $P = 0.0553$; 1.63 ± 0.74 (mean \pm standard deviation) food items per trip for males and 1.52 ± 0.73 food items per trip for females). Males tended to carry slightly larger food items, however (Mann-Whitney, $P = 0.0011$; 1.50 ± 0.39 cm for males versus 1.38 ± 0.38 cm for females). Lepidoptera larvae and pupae, in particular Spruce Budworm, were by far the most common items in the diets of nestlings. Lepidoptera comprised 93.6% of the food brought to nestlings by males, and 87.9% of the food brought by females. This difference was significant ($G_{\text{adj}} = 4.088$, $P < 0.05$)

Females significantly increased nestling feeding rates as nestlings aged (Table 2; feedings/h, $r_s = 0.6793$, $N = 34$, $P < 0.0001$; biomass/h, $r_s = 0.6522$, $N = 32$, $P = 0.0001$). The same trend was seen among males, but it was not significant (Table 2; feedings/h, $r_s = 0.2978$, $N = 34$, $P = 0.0871$; biomass/h, $r_s = 0.1687$, $N = 32$, $P = 0.3560$).

Pairs significantly increased the quantity of food they delivered to nestlings with increasing brood size (Figure 3; $r_s = 0.3928$, $N = 31$, $P = 0.0288$). Males were primarily responsible for this increase ($r_s = 0.4304$, $N = 32$, $P = 0.0139$). The number of feeding trips per hour per pair also increased with increasing brood size, but not significantly ($r_s = 0.2221$, $N = 34$, $P = 0.2067$). On a per-nestling basis, both biomass delivered and number of feeding trips per hour per pair declined with increasing brood size, but neither of these trends was significant (Figure 4; biomass/nestling/h, $r_s = -0.0918$, $N = 31$, $P = 0.6232$; feedings/nestling/h, $r_s = -0.1549$, $N = 34$, $P = 0.3819$).

Growth rates of individual Tennessee Warbler nestlings were calculated by simple regression. Broods of 4, 5, 6 and 7 nestlings had average growth rates (mean \pm standard deviation) of 1.24 ± 0.10 , 1.28 ± 0.05 , 1.29 ± 0.18 and 1.19 ± 0.09 g/d, respectively. There was a significant negative correlation between growth rate and brood size ($r_s = -0.3156$, $N = 56$, $P = 0.0178$).

Discussion

Nest site selection

Tennessee Warbler nests have been found on dry hillsides, along muskeg borders and clearing edges in coniferous and coniferous-deciduous forests, in shrubby areas and in heavy growths of dry pine grass (Bowdish and Philipp 1916; Godfrey 1966; Harrison 1984; Ehrlich et al. 1988). Most nest records, however, refer to boggy, wet areas, particularly black spruce, larch or cedar bogs, with the nests often built in hollows dug in sphagnum moss hummocks (Bowdish and Philipp 1916; Harrington in Bent 1953; Baker 1979; Ehrlich et al. 1988). There are also records of Tennessee Warblers nesting in loose colonies under ideal habitat situations, with as many as 100 pairs observed nesting in one corner of a sphagnum bog (Brown and Terrill in Bent 1953).

In our study area, most Tennessee Warbler nests were found on drier sites. Tennessee Warblers were frequently seen foraging in boggy or wet areas, particularly on speckled alder, but we found no nests there. We also found no evidence of colonial nesting.

Incubation period

The 7-8 day period from the laying of the last Tennessee Warbler egg to the hatching of the first nestling is exceptionally short. Kendeigh (1945) states that the incubation period for wood warblers is normally 12 days, and Harrison (1975) and Ehrlich et al. (1988) give incubation periods for wood warblers ranging from 10-11 days (e.g., Blue-winged Warbler, *Vermivora pinus*; Golden-winged Warbler, *V. chrysoptera*; Black and White Warbler, *Mniotilta varia*) to 13-16 days (e.g., Kirtland's Warbler, *Dendroica kirtlandii*).

Another species with an unusually short incubation period (i.e., apparently <10 days; see Nice 1953) is the Yellow Warbler, *D. petechia*. Bent (1953) reported an incubation period of 8-11 days for this species, and Goossen and Sealy (1982) found that on average 9 days elapsed between the laying of the last egg and the hatching of the first Yellow Warbler nestling. However, incubation in Yellow Warblers may begin before the clutch is complete (see Bent 1953), so that

the actual incubation period (interval from the laying of the final egg until its hatching, as opposed to the hatching of the first nestling; see Nolan 1978) could be somewhat longer. The same may be the case for Tennessee Warblers. While we did not make any observations on the onset of incubation, the fact that in 60% of our nests the hatching interval exceeded 24

hours suggests that incubation may have commenced prior to the laying of the last egg.

The apparently short incubation period of Tennessee Warblers is not likely an adaptation to nest predation, as nest predation rates are low for ground-nesting birds in forests in general (Martin 1993), and for Tennessee Warblers in particular (see below). It

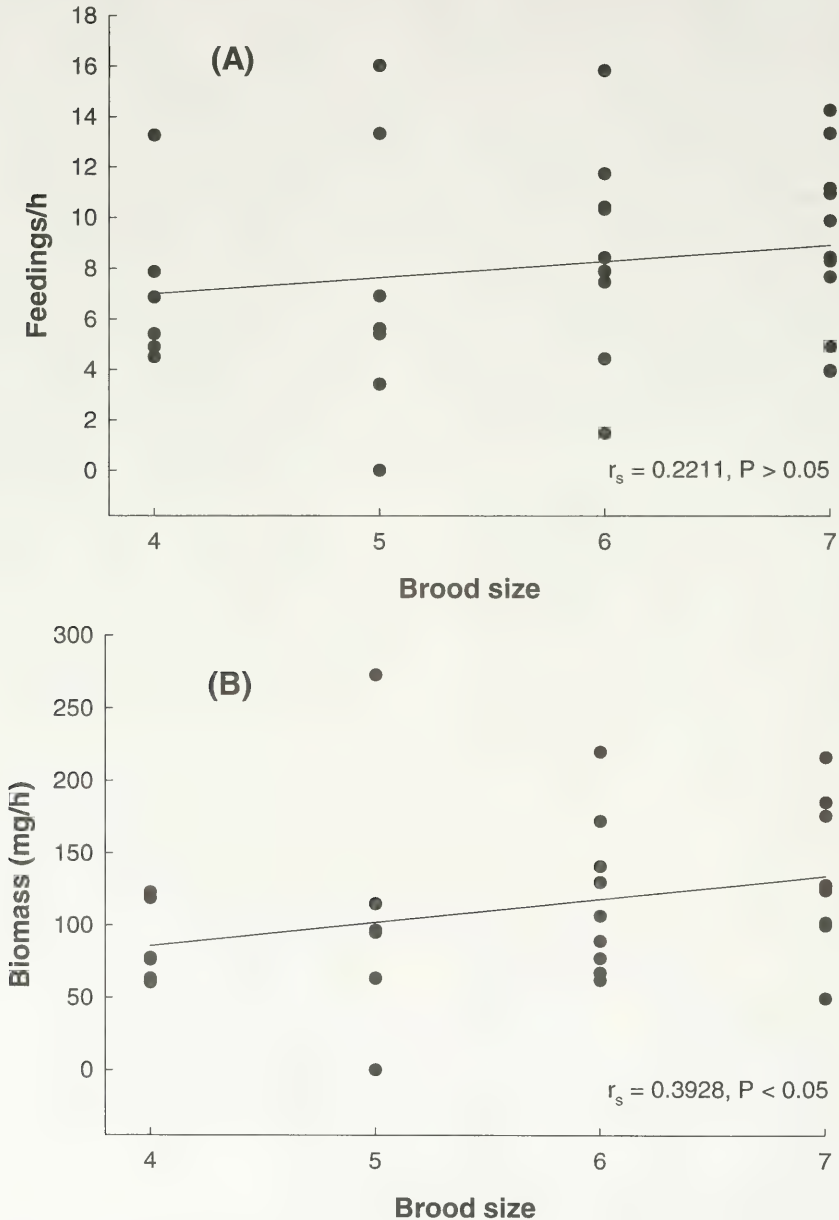


FIGURE 3. Feeding rates (A) and quantities of food delivered (B) to broods of various sizes by Tennessee Warbler parents.

may be that a short incubation period has evolved to facilitate synchronization of the nestling period with the period when the nestlings' preferred food (i.e., late instar spruce budworm larvae and pupae) is most readily available. This would only be possible if there was some factor linking budworm development and

the onset of laying and/or incubation (e.g., if they were tuned to the same environmental condition, such as spring temperature). Such a mechanism has been suggested for the Great Tit, *Parus major*, another species that exploits a pulsed resource (caterpillars on oak) to feed its young (Van Balen 1973).

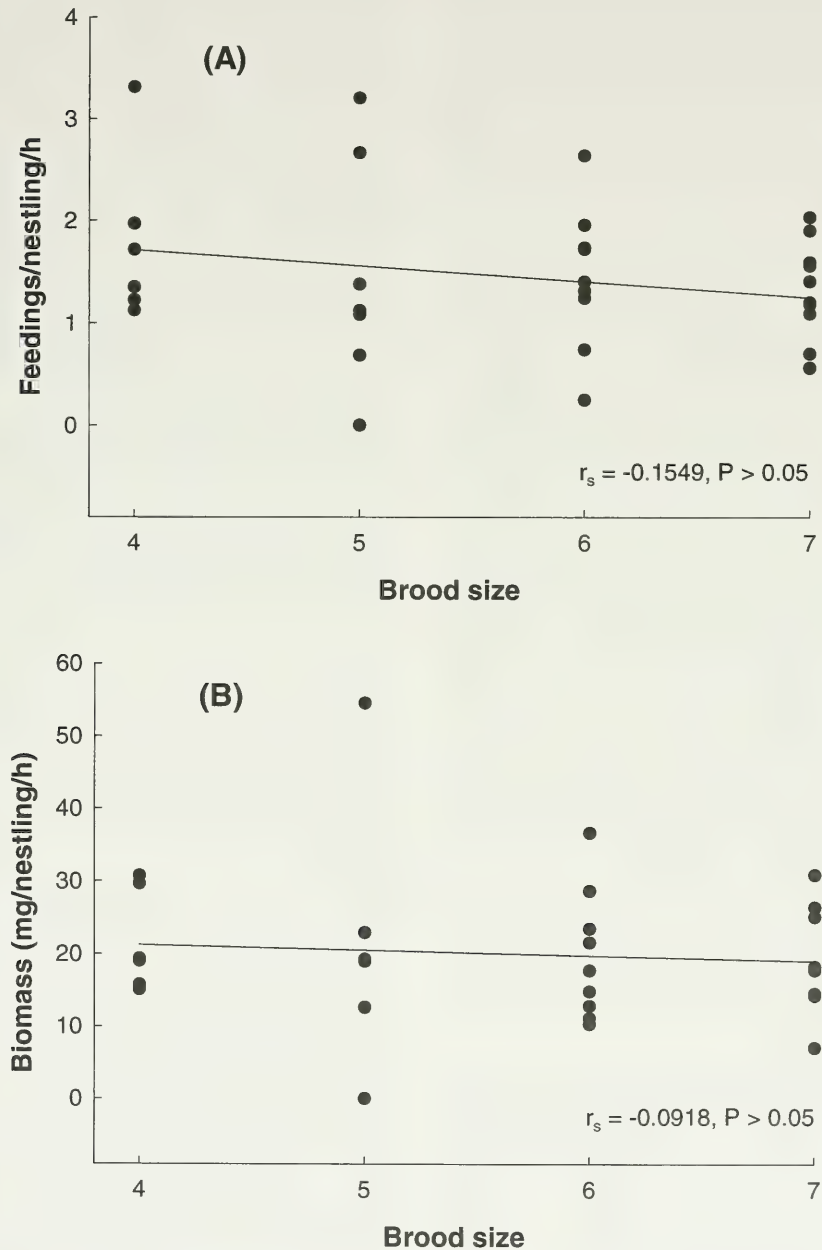


FIGURE 4. Feeding rates (A) and quantities of food delivered (B) to individual nestlings in broods of various sizes by Tennessee Warbler parents.

Nest success

Martin (1992, 1993) reported Mayfield estimates for 10 ground-nesting songbird species (mean = 43.2%, range = 20-58%). By comparison, the Mayfield nest success rate for Tennessee Warblers in this study (73.3%) was very high. However, we were only able to follow Tennessee Warbler nests until the nestlings were about 6-7 days old. If the mortality rate of Tennessee Warbler nests was significantly higher in the second half of nestling life (ages 7-12 days) compared to the first half, then the Mayfield nest success rate may have been overestimated. Morse (1989) suggested that older nestlings might be more prone to predation, because their parents make more feeding trips to the nest. Also, the nestlings themselves may be noisier and thus more obvious to predators (Clark and Wilson 1981).

One of the reasons for this study's high nest success estimate was that no nests were lost during incubation (50 nest-days of observation), compared to two nests lost during the nestling period (72 nest-days of observation). Others have found that nest mortality rates during incubation are similar to (Mayfield 1975), or greater than (Martin 1992) those in the nestling stage. Our sample size may have been too small to detect a low level of predation during the incubation period. If we assume a similar nest survival rate during incubation as during the nestling period (i.e., $1 - (2/72) = 0.9722$), then the Mayfield estimate of nest success becomes 58.5% (i.e., $0.9722^8 \times 0.9722^{11}$). This estimate is still high compared to most other published data (e.g., Mayfield 1961; Martin 1992, 1993; Sargent et al. 1997), but close to the values obtained by Martin (1992) for 3 of 4 ground-nesting warblers (Orange-crowned Warbler, *Vermivora celata*, 50.1%; Virginia's Warbler, *V. virginiae*, 58.0%; Red-faced Warbler, *Cardellina rubrifrons*, 51.8%; but Kirtland's Warbler, 20.1%).

Finally, the high nest success measured in our study may simply be the product of an unusually good breeding season in this locality. As such, it would be more indicative of the high end of the range of breeding success for this species rather than of the mean. Nice (1957) cautions against putting too much confidence in a single year's data in cases where nesting success is markedly higher or lower than the norm.

Fecal sac removal

Many species of warblers and other passerines remove nestling fecal sacs from their nests, either by eating them or by carrying them away (e.g., Yellow Warbler, Black-throated Blue Warbler, *Dendroica caerulescens*, Ovenbird, *Seiurus aurocapillus*, Common Yellowthroat, *Geothlypis trichas*, American Redstart, *Setophaga ruticilla*, Bell's Vireo, *Vireo bellii*, Nashville Warbler, *Vermivora ruficapilla*, Prairie Warbler, *Dendroica discolor*,

Mountain White-crowned Sparrow, *Zonotrichia leucophrys oriantha*) (Bent 1953; Barlow 1962; Roth 1977; Nolan 1978; Morton 1979). Two advantages associated with removing fecal sacs are the maintenance of a warm, dry, sanitary nest, and a reduced chance of attracting predators to the nest (see Petit and Petit 1987). A third potential advantage is that the adults may derive some nourishment from ingesting their nestlings' wastes (Morton 1979; Alcorn 1991).

In our study, Tennessee Warbler parents ate nestling fecal sacs when the nestlings were 1-2 days old, but usually carried them away when the nestlings were older. While a similar pattern has been observed in other species, the length of time that the fecal sacs were eaten differs. For example, Ovenbirds and American Redstarts ate fecal sacs for only the first couple of days of nestling life (Bent 1953), while Black-throated Blue Warblers, Yellow Warblers and Bell's Vireos ate fecal sacs for up to 5 days or more (Bent 1953; Barlow 1962). The reasons for this difference are unknown, but may be related to nestling diet and post-hatching maturation of the gut. Morton (1979) found that the digestive capacity of White-crowned Sparrows increased markedly during the first few days of nestling life. It may be that nestlings fed primarily on soft bodied, easily digestible insect larvae, as are Tennessee Warblers, are able to extract a greater proportion of the nutrients from their food at a younger age. Thereafter, the parents would have less reason to eat their nestlings' feces, since these would have lower nutritional value.

Nestling provisioning rate

Male Tennessee Warblers provisioned their nestlings at higher rates (feedings/h and biomass/h) than did their mates. Similar observations have been made for other passerine species (e.g., Kendeigh 1945; Roth 1977; Bierman and Sealy 1982; Grundel 1987; Moreno 1987; Filliater and Breitwisch 1997). This tendency is not universal, however. In some species, males and females feed at similar rates or provide approximately equal quantities of food to their nestlings (e.g., Bédard and Meunier 1983; Knapton 1984; Breitwisch et al. 1986; Goodbred and Holmes 1996). Others show an opposite tendency, with female feeding rates higher than male rates (e.g., Pinkowski 1978; Howe 1979).

The difference between male and female provisioning rates was most evident for the first few days of nestling life, probably because females spent >60% of their time brooding during this period. A similar pattern has been reported for other passerine species (e.g., Royama 1966; Johnson and Best 1982; Moreno 1987). From nestling age 3-4 days, Tennessee Warbler females increased their feeding rates (trips/h) to equal or exceed those of the males. However, females never achieved the same level of

nestling provisioning (biomass of food delivered) as males, because males tended to bring larger food loads (more and larger items) to the nest. The food brought to nestlings by males also tended to be more nutritious (i.e., a higher proportion of Lepidoptera; see Bell 1990).

A positive relationship between feeding rate/biomass delivery rate and nestling age has been reported in several passerine species, at least during the early part of nestling life (e.g., Howe 1979; Biermann and Sealy 1982; Johnson and Best 1982; Wittenberger 1982; Bédard and Meunier 1983; Breitwisch et al. 1986; Haggerty 1992; Rosa and Murphy 1994; Filliater and Breitwisch 1997). This tendency has been related to increasing energy demands of the young (Goodbred and Holmes 1996). Later in the nestling period, feeding/delivery rates may plateau or decline (e.g., Royama 1966; Pinkowski 1978; Haggerty 1992; Grundel 1987; Moreno 1987), as growth levels off and thermoregulatory demands are reduced. This appears to be the case for Tennessee Warblers, beginning at about age 5–6 days.

Total feeding rates by adult Tennessee Warblers increased with increasing brood size. When expressed on a per-nestling basis, however, nestling feeding rates declined as brood size increased. A similar pattern has been observed in other songbird species (e.g., Best 1977; Moreno 1987; Rosa and Murphy 1994; Filliater and Breitwisch 1997; but see Pinkowski 1978; Bédard and Meunier 1983). A decline in per-nestling feeding rate with increasing brood size suggests that either the parents may not be able to compensate for the higher demands of larger broods by increasing their feeding rates (Moreno 1987), or the food requirements/thermoregulatory costs of nestlings in larger broods may be less (Johnson and Best 1982). For broods of 4, 5 and 6 Tennessee Warbler nestlings, the latter explanation appears to hold. There was little difference in growth rates in this range of brood sizes. However, the relatively low average growth rate of nestlings in broods of 7 nestlings suggests that brood sizes larger than 6 may exceed the provisioning capacity of parents.

Acknowledgments

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Cetacean Strandings on Sable Island, Nova Scotia, 1970-1998

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Lucas, Zoe N., and Sascha K. Hooker. 2000. Cetacean strandings on Sable Island, Nova Scotia, 1970-1998. *Canadian Field-Naturalist* 114(1): 45-61.

Two hundred and sixty-seven cetaceans, in 102 stranding events, were recorded between 1970 and 1998 on Sable Island off the coast of Nova Scotia. Seventeen species were represented: Blue Whale (1 single stranding), Fin Whale (1 single stranding), Minke Whale (3 single strandings), Humpback Whale (4 single strandings), Sperm Whale (8 strandings, 13 animals), Pygmy Sperm Whale (3 strandings, 4 animals), Dwarf Sperm Whale (2 single strandings), Northern Bottlenose Whale (3 single strandings), Sowerby's Beaked Whale (1 single stranding), Killer Whale (1 single stranding), Long-finned Pilot Whale (37 strandings, 173+ animals), White-beaked Dolphin (1 stranding, 2 animals), Atlantic White-sided Dolphin (9 strandings, 13 animals), Risso's Dolphin (1 single stranding), Striped Dolphin (8 strandings, 22 animals), Short-beaked Common Dolphin (4 strandings, 6 animals), Harbour Porpoise (11 strandings, 13 animals). The records of the Dwarf Sperm Whale and that of the Risso's Dolphin are the first for eastern Canada. The record of the Sowerby's Beaked Whale is the first reported stranding in Nova Scotia. Humpback, Minke, and Killer whales, and Short-beaked Common Dolphins have not previously been recorded stranded on Sable Island. The majority of stranding events (84) were of a single animal; nine involved two animals; eight involved 3-10 animals; and one event involved over 130 animals. Recorded strandings increased from 1.9 strandings/year between 1970-1989 to 7.1 strandings/year between 1990-1998. Mass strandings of multiple male Sperm Whales have occurred three times (all since 1990). All Atlantic White-sided Dolphin strandings investigated were also comprised of male animals.

Key Words: cetacean, stranding, Sable Island, Nova Scotia.

Monitoring beach cast cetaceans can provide information on spatial distribution, seasonal movements, and mortality factors (Woodhouse 1987). Brabyn and McLean (1992) noted that gently sloping sandy beaches with currents moving toward the beach often result in mass strandings. Sable Island (44°N, 60°W), a 40 km-long sand bar located roughly 170 km southeast of mainland Nova Scotia and 40 km north of the edge of the continental shelf (Figure 1), fits this general model. Many cetacean stranding hot-spots are associated with a hook of land at one end (Brabyn and McLean 1992), and the sand bars at either end of Sable may similarly serve as a trap for cetaceans. The main body of the island is oriented roughly west-east, and the ends of the island curve northwards (Figure 1).

Stranding records on Sable up to 1969 were reviewed by Sergeant et al. (1970) but no compilations have been presented since then. Most of these earlier reports were made by researchers with Fisheries and Oceans, Canada, who spent between two and six weeks on the island each year during the Harbour Seal (*Phoca vitulina*) and Grey Seal (*Halichoerus grypus*) breeding seasons (May-June and January-February, respectively). Here we present a detailed compilation of stranded cetacean records for Sable Island for the twenty-nine years since Sergeant et al.'s (1970) report; i.e., from 1970 to 1998. Records between 1970 and 1989 have been collected from a variety of published and unpub-

lished sources. Records between 1990 and 1998 were based on more comprehensive survey effort on the island.

Methods

During 1970 to 1989 there was little attempt to keep track of stranded cetaceans on Sable Island. Strandings data for this period have been compiled primarily from unpublished reports provided by personnel living on or visiting Sable Island; a few records were previously published. In most cases very few details are available for these early records, but verification of the observations, and information regarding condition of carcass, were obtained through interviews and photographs.

Between 1990 and 1998, most data were collected by Z. Lucas while working on the island during nine to eleven months each year, with little seasonal bias in effort. During this time, beaches were inspected roughly once every two weeks. Available time and beach conditions influenced the amount of data collected at each event. Due to the limitation of working alone, it was not possible to move some of the larger animals for examination and precise measurements. Therefore, data collected amounted to whatever was expedient at the time, and varied from a species record, to collection of some standard measurements, tissues and photographs. Survey effort was most comprehensive during 1998.

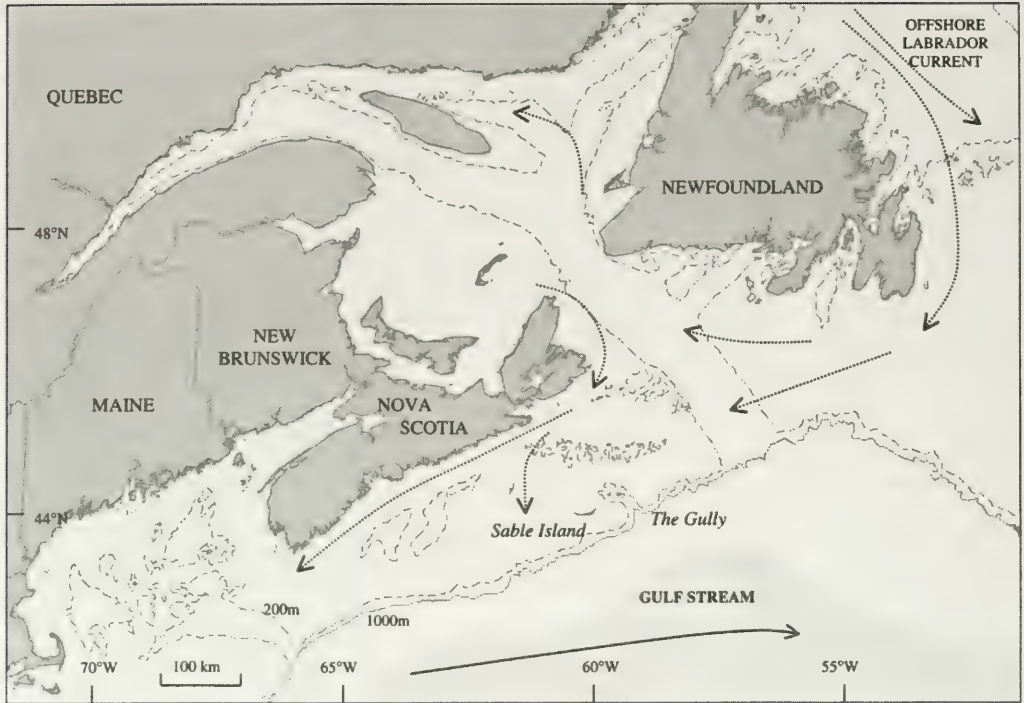


FIGURE 1. Map showing location of Sable Island and major surrounding surface water currents. The Gully, a submarine canyon adjacent to Sable Island, is also shown. The 1000 m and 200 m isobaths show the location of the shelf edge. Gulf stream fluctuates seasonally. (Currents based on Sutcliffe et al. 1976.)

Specimens in an advanced state of decomposition (with large pink-coloured areas resulting from loss of much of the epidermis after rolling in the surf along the beach) or with damage caused by shark scavenging, were assumed to have died at sea. Fresh specimens with no shark scavenging damage and little pink colour from chafing were assumed to have died on the beach or in waters near the island. In cetaceans for which the melon extended beyond the upper jaw, the whale's length (to notch in flukes) was measured from the furthest anterior point of the melon.

Results and Discussion

Seventeen species of cetaceans were recorded stranded on Sable Island between 1970-1998 (Table 1). Generally the species composition of records between 1970-1989 is consistent with the records between 1990-1998, although a far greater number of stranding events was recorded in the 1990-1998 period (mean = 7.1/year) than in the earlier period (mean = 1.9/year). Below we discuss findings for each species found stranded on Sable Island, then present a more general discussion of stranding trends over the duration of this study.

Species Accounts

FAMILY – BALAENOPTERIDAE

Blue Whale, *Balaenoptera musculus*

The single Blue Whale record was of a well-decomposed adult, which washed ashore on the north side of the island in January 1974 (Table 2). The carcass was half in the water and only the cranium, 520 cm long, was measured (P. F. Brodie, personal communication). The skull was removed by Canadian Coast Guard in the 1980s, apparently for delivery to the Nova Scotia Museum of Natural History in Halifax, but its whereabouts are now unknown.

A Blue Whale was previously reported stranded on Sable Island in 1958 (Sergeant et al. 1970). Blue Whales are regularly found in the Gulf of St. Lawrence and are thought to be distributed in low numbers throughout the North Atlantic (Mansfield 1985; Sears et al. 1990). The Blue Whale population in the North Atlantic was heavily impacted by whaling and some whales were taken from the Scotian Shelf by the whale fishery in Nova Scotia based out of Blandford (Sutcliffe and Brodie 1977). Hooker et al. (1999) observed Blue Whales on 3 and 5 occasions during August 1996 and 1997 respectively in the Gully, a submarine canyon adjacent to Sable Island (Figure 1).

TABLE 1. Number of stranding events and number of individuals are shown for each species recorded on Sable Island during 1970–1989 and 1990–1998.

Species	1970 - 1989		1990 - 1998		Total	
	Events	Individuals	Events	Individuals	Events	Individuals
Blue Whale	1	1	—	—	1	1
Fin Whale	—	—	1	1	1	1
Fin/Sei Whale	2	2	1	1	3	3
Minke Whale	1	1	2	2	3	3
Humpback Whale	1	1	3	3	4	4
Sperm Whale	4	4	4	9	8	13
Pygmy Sperm Whale	1	1	2	3	3	4
Dwarf Sperm Whale	1	1	1	1	2	2
Northern Bottlenose Whale	2	2	1	1	3	3
Sowerby's Beaked Whale	—	—	1	1	1	1
Killer Whale	1	1	—	—	1	1
Long-Finned Pilot Whale	16	149+	21	24	37	173+
White-Beaked Dolphin	—	—	1	2	1	2
Atlantic White-Sided Dolphin	3	3	6	10	9	13
Short-Beaked Common Dolphin	—	—	4	6	4	6
Risso's Dolphin	—	—	1	1	1	1
Striped Dolphin	1	2	7	20	8	22
Unidentified Dolphin	—	—	1	1	1	1
Harbour Porpoise	4	5	7	8	11	13
Total	38	173+	64	94	102	267+
Total species	12		15		17	

**Fin Whale, *Balaenoptera physalus*, and
Sei Whale, *Balaenoptera borealis***

Three very decomposed baleen whales washed ashore in 1982, 1990 and 1994 (Table 2). One was identified as a Fin Whale (P. F. Brodie, personal communication), and on the basis of size, the other two were thought to be either Fin or Sei Whales. A fourth *Balaenoptera* sp., seen on south beach in August 1981, was described as “large” and was likely, also, to have been a Fin or Sei Whale. This animal had seven to eight parallel slashes (45-75 cm long) on the rostrum (G. Forbes, personal communication). The whale was alive and bleeding, but no other information was recorded. This is the only baleen whale known to have been alive when stranded on Sable Island.

Skulls likely to have been from Fin Whale strandings were reported on Sable Island prior to 1970 (Sergeant et al. 1970). Fin and Sei Whales are thought to be fairly numerous over the Scotian Slope (Mitchell 1974) and both were taken in large numbers during whaling out of Blandford (Mitchell 1974; Sutcliffe and Brodie 1977).

Minke Whale, *Balaenoptera acutorostrata*

Three decomposed Minke Whales have been identified on the island (Table 2). One was estimated to be 780 cm in length and therefore likely adult (Sergeant 1963), but no other information was collected. In December 1998 a very decomposed carcass of a baleen whale, approximately 800 cm long and of unknown sex, was found on the north beach.

Within 1 km, on the same beach, was a male baleen whale fetus, roughly 190 cm long, also decomposed. It was not possible to identify either carcass on the basis of colour pattern. However, it seems likely that the fetus belonged to the large animal, in which case the latter must have been a female Minke Whale (sexually mature at 730 cm, Sergeant 1963).

Minke Whales have been found as far south as the Gulf of Mexico, and have stranded or been captured in New England waters and in the Bay of Fundy (Mitchell 1991). Minke Whales were also taken during the Blandford whale fishery (Sergeant 1963).

Humpback Whale, *Megaptera novaeangliae*

Of the four Humpback Whales found on Sable Island since 1970 (Table 2), only one was relatively fresh and may have died not far from the island. This carcass, a 1260 cm female, was found in May 1993 distended with gas and lying on its back at the water's edge. The dorsal surface could not be examined, but otherwise there were no injuries or scavenging on the body, and there was no discolouration or abrasion of the epidermis. No measurements were collected for the three decomposed Humpback Whale carcasses, but it was noted that one of these was entangled in gill net when it washed ashore on the south side of the island in January 1992.

Humpback Whales have not previously been reported stranded on Sable Island, although they are seen fairly often in the Gully during summer months (Hooker et al. 1999). Humpback Whales are also occasionally seen close to the island (see

Observations of Live Cetaceans). The population of Humpback Whales in the western north Atlantic is believed to have recovered to levels approaching those of pre-whaling times (Whitehead 1987).

FAMILY – PHYSETERIDAE

Sperm Whale, *Physeter macrocephalus*

Thirteen Sperm Whales, in eight stranding events, have been reported on Sable Island since 1970 (Table 3). Two of these events (1990 and 1992) were noted by Reeves and Whitehead (1997). Five of the eight events were of single individuals. There is no information on carcass condition for the 1977 and 1984 specimens, but the other three single strandings were decomposed and had been scavenged at sea. One of these, the March 1992 specimen, washed ashore on the south side of the island with its lower jaw missing and a rope tied around the tail stock. This suggests that the whale may have been found dead at sea, and temporarily secured in order to remove the jaw. The single stranded animal in 1987 was a very large male; its length was paced off at roughly 1650 cm. Two of the five single specimens, those of 1983 and 1984, were described as “not adult” (S. Boates and G. Forbes, personal communication).

Since 1990, three mass strandings of either two or three males have occurred on the north beach. A stranding of two males occurred in October 1990. Another group stranding of three males occurred in 1992. Two of these were measured at roughly 850 and 1050 cm and one of these measured whales had a broken lower jaw. The bone was splintered and the presence of distorted/crooked teeth at the site of the break indicated that the jaw had been broken long before death.

The group stranding event of three males in January 1997 was observed by researchers working on the island at the time. When first found, at about 09:00, two whales had just stranded, and both were active, slapping flukes and rolling. A third whale was in the distance offshore and appeared to be swimming roughly parallel to the beach. Eventually this individual moved closer to the beach, appearing to head directly toward the first two, and soon after stranded within 50 m of the others (S. Iverson, Biology Department, Dalhousie University, Halifax, personal communication). Measurements in centimetres for these three males, length and half girth (taken at tip of flipper), were roughly 1155 (half girth 305), 1280 (half girth 345), and 1310 (half girth 355). The 1155 cm long male had double teeth in two sockets (the 12th and 13th from the front) of the left jaw.

Sex was recorded for eleven of the thirteen specimens, and all were male. The all-male composition of Sperm Whale strandings is not surprising as females only occasionally use the southernmost waters of Atlantic Canada (Reeves and Whitehead

TABLE 2. Balaenopteridae: baleen whales.

Date	Species	Number	Type	Bch	Sex	Photo	Samples	Length (cm)	Source
January 1974	Blue Whale	1	D-nf	N	-	✓	-	-	P. F. Brodie, Halifax, N.S.; R.F. Addison, DFO
August 1981	Fin/Sei Whale	1	L	S	-	-	-	-	G. Forbes, Environment Canada
spring 1982	Minke Whale	1	D-nf	S	-	-	-	~780	B. Wright, Lunenburg, N.S.
July 1982	Fin/Sei Whale	1	D-nf	S	-	-	-	-	G. Forbes; S. Crowell, Barrington, N.S.
spring 1983	Humpback Whale	1	D-nf	S	-	-	-	-	S. Crowell
4 November 1990	Fin Whale	1	D-nf	N	-	-	-	-	L. Morton, Pleasantville, N.S.; Z. Lucas
November 1991	Humpback Whale	1	D	-	-	-	-	-	Nova Scotia Stranding Network
4 January 1992	Humpback Whale	1	D-nf	S	-	-	-	-	Z. Lucas; J. Parsons
January 1992	Minke Whale	1	D	-	-	-	-	-	Nova Scotia Stranding Network
3 May 1993	Humpback Whale	1	D-f	S	f	✓	-	1260	Z. Lucas
August 1994	Fin/Sei Whale	1	D-nf	-	-	-	-	-	Z. Lucas
13 December 1998	Minke Whale	1	Ds	N	-	✓	jaw of fetus	~800	Z. Lucas
Notes:	Type:	Beach (Bch):				Sex:	Samples:		
	D-nf: Dead, not fresh	N: north				f: female	sk: skin		
	D-f: Dead, fresh	S: south				m: male	bl: blubber		
	D: Dead, no information on condition	E: east bar					t: teeth		
	Ds: Dead, scavenged at sea	W: west bar					m: muscle		
	L-D: live stranding, died								
	L: live stranding, not seen again								

Except where otherwise noted, all photographs, measurements, and specimens (skull, jaw, teeth, skin, blubber, muscle tissues) are deposited at the New Brunswick Museum (227 Douglas Avenue, Saint John, New Brunswick E2K 1E5, Canada).

1997). Male Sperm Whales are commonly found in the Gully (Whitehead et al. 1992). Length was measured for six of the thirteen specimens. Only three of these animals (~16.5 m, ~13.1 m, ~12.8 m) were sexually mature (> 12 m; Rice 1989). Thus at least half of the measured male Sperm Whales found were probably not yet sexually mature and a further two were noted as being of small size, likely young or subadult (although the sex was not recorded for either). Mass strandings of groups of male Sperm Whales have also been reported from the eastern Atlantic but were composed of mature males (Jauniaux et al. 1998) whereas many of the whales stranded in this study were not yet mature.

A single "old male" Sperm Whale was previously reported stranded on Sable in February 1964 (Mansfield 1967; Sergeant et al. 1970). It is interesting to note that all strandings prior to 1990 were of single individuals, but that there have been three mass-stranding events (of two or three individuals) and only one single stranding since then.

FAMILY – KOGIIDAE

Pygmy Sperm Whale, *Kogia breviceps*, and

Dwarf Sperm Whale, *Kogia simus*

Six *Kogia* specimens have been found on Sable Island since 1970 (Table 4). Of these, three could be positively identified as *K. breviceps*, and one as *K. simus*. The specimen found in January 1971 was identified from photographs as a probable *K. simus* (N. Barros and D. Odell, SeaWorld, Orlando, personal communication). The specimen found in January 1986 was identified as a probable *K. breviceps* by researchers with Fisheries & Oceans Canada. The stranded whale in 1991 was alive when found, and cursory examination revealed that its body cavity was filled with blood (B. Beck, personal communication). Additional details on these *Kogia* will be provided by Lucas et al. (in preparation).

There has been one previous record of a stranded Pygmy Sperm Whale on Sable Island, during January 1969 (Sergeant et al. 1970; Baird et al. 1996), and four other records from eastern Canada and the Gulf of St. Lawrence (Piers 1923, cited in Baird et al. 1996; Sergeant et al. 1970; Nelson et al. 1991; McAlpine et al. 1997).

The two strandings of Dwarf Sperm Whales reported here are the first records of this species in eastern Canada. The 1996 record was reported in Lucas and Hooker (1997) and in Willis and Baird (1998). The most northerly record of this species prior to these was in Virginia (Allen 1941, in Willis and Baird 1998).

FAMILY – ZIPHIIDAE

Northern Bottlenose Whale,

Hyperoodon ampullatus

Three Northern Bottlenose Whales have been found on Sable Island since 1970 (Table 5). The

specimen found in February 1974 was previously reported by Mitchell and Kozicki (1975). The second, a 525 cm male, was found on the south beach in July 1985. Although the carcass was intact and tissues were relatively fresh, extensive chafing of the epidermis suggested that the animal had died at sea. A third specimen, an approximately 750 cm female, was well decomposed and entirely pink when it washed ashore in May 1992.

A single Northern Bottlenose Whale was reported on Sable Island in January, 1968 (Sergeant et al. 1970), but the authors note that this may have been an animal killed or injured in whaling operations. Bottlenose Whales in the Gully were hunted between 1963 and 1968, during which time 68 animals were taken (Reeves et al. 1993; Whitehead et al. 1997a). The Gully is one of two main centers of Bottlenose Whale distribution in the western North Atlantic. The other is in the Labrador Sea (Reeves et al. 1993). The population of Northern Bottlenose Whales in the Gully is currently thought to number approximately 230 animals (Whitehead et al. 1997b).

Sowerby's Beaked Whale, *Mesoplodon bidens*

The only *Mesoplodon* in the island's records is a 488 cm female Sowerby's Beaked Whale, found in June 1997 on the south beach (Table 5). Identification was confirmed by the presence of a single tooth beneath the gum in the middle of each lower jaw. It was a fresh carcass with only a small amount of scavenging by gulls and the stomach was empty. There were several long, deep, fresh wounds on the left side of the head, shoulder and flank just behind the front flipper, and several "dents" in the mid-flank area. Further examination revealed eight broken ribs beneath these dents. These wounds suggest a vessel-strike as the possible cause of death.

Scattered on the whale's body were 6 to 8 round holes with smooth margins, 5-6 cm across and 3-4 cm deep, characteristic of the wounds made by Cookiecutter Sharks (*Isistius brasiliensis*) often seen on beaked whales (Mead 1989). It was not possible to determine how recently the wounds had been inflicted. The Cookiecutter Shark is found worldwide in tropical and subtropical waters, and in regions of warm currents this species extends into somewhat higher latitudes (Jahn and Haedrich 1987; Muñoz-Chápuli et al. 1988). Jahn and Haedrich (1987) note, however, that the Cookiecutter Shark has not been found in the well-sampled Gulf Stream regions. In the Caribbean and the east coast of South America, cookiecutter wounds have been found on Humpback Whale, Arnoux's Beaked Whale (*Berardius arnuxii*), Gervais' Beaked Whale (*Mesoplodon europaeus*), Melon-headed Whale (*Peponocephala electra*), and Spinner (*Stenella longirostris*) and Clymene (*Stenella clymene*) Dolphins (see Debrot and Barros 1992; Gasparini and Szalma 1996). Such wounds on the specimen reported here

TABLE 3. Sperm Whale.

Date	Number	Type	Beach	Sex	Photo	Samples	Length (cm)	Source
April 1977	1	D	W	-	-	-	-	B. Wright, Lunenburg, N.S.
July 1983	1	Ds	S	-	-	-	>600	S. Boates, N.S. Natural Resources
February 1984	1	D	W	m	-	-	small	G. Forbes
March 1987	1	Ds	N	m	-	-	~1650	S. Crowell; G. Forbes
6 October 1990	2	D	N	2m	✓	-	-	Z. Lucas (previously reported in Whitehead et al. 1992; Reeves and Whitehead 1997)
17 January 1992	3	D	N	3m	-	sk	~850, ~1050	Z. Lucas (previously reported in Reeves and Whitehead 1997)
March 1992	1	Ds	S	m	-	-	-	G. Forbes
13 January 1997	3	L-D	N	3m	✓	sk	1155 - 1310	Z. Lucas

see footnotes to Table 2

TABLE 4. Kogidae: Pygmy and Dwarf sperm whales.

Date	Species	Number	Type	Beach	Sex	Photo	Samples	Length (cm)	Source
January 1971	Dwarf Sperm Whale?	1	D	-	-	✓	-	-	A. Mansfield, Rigaud, Quebec
January 1986	Pygmy Sperm Whale?	1	D	N	-	✓	-	-	M. Strong, DFO
1991	Pygmy Sperm Whale	1	L-D	N	-	-	-	-	B. Beck, formerly DFO
30 September 1996	Dwarf Sperm Whale	1	D-f	S	m	✓	sk, t	226	Z. Lucas (teeth held by Z. Lucas)
18 November 1996	Pygmy Sperm Whale	2	L-D	S	m, f	✓	sk, bl, t, skull, fetus	180, 305	Z. Lucas (skull and teeth held by Z. Lucas)

see footnotes to Table 2

TABLE 5. Ziphiidae: beaked whales.

Date	Species	Number	Type	Beach	Sex	Photo	Samples	Length (cm)	Source
2 February 1974	Bottlenose Whale	1	D-f	S	m	-	-	~820	Mitchell and Koziacki, 1975
1 July 1985	Bottlenose Whale	1	D	S	m	✓	-	525	Z. Lucas; P.F. Brodie, Halifax, N.S.
18 May 1992	Bottlenose Whale	1	D-nf	S	f	✓	-	~750	Z. Lucas
20 June 1997	Sowerby's Beaked Whale	1	D-f	S	f	✓	sk, bl, skull	488	Z. Lucas (skull held by Z. Lucas)

see footnotes to Table 2

suggest that either Cookiecutter Sharks frequent waters further north than previously documented, or that this whale had spent time in waters well south of Nova Scotia.

This is the first report of a Sowerby's Beaked Whale stranded in Nova Scotia. Only seven strand-

ings (involving 14 animals) have been reported previously in the Northwest Atlantic (Sergeant and Fisher 1957; Dix et al. 1986; Lien and Barry 1990; Lien et al. 1990). Of these, five (including the only two mass strandings) occurred in Newfoundland and Labrador. The remaining two strandings, both of sin-

TABLE 6. Long-finned Pilot Whales

Date	Number	Type	Beach	Sex	Photo	Samples	Length (cm)	Source
January 1970	1	Ds	—	—	—	—	—	P. Thorne, Environment Canada
30 November 1970	1	Ds	N	—	—	—	—	J. Boulva, DFO
1 December 1970	1	Ds	S	m	—	—	600	J. Boulva
19 April 1971	1	D-f	N	m	✓	—	~140	J. Boulva
25 June 1971	1	D-nf	N	—	—	—	—	J. Boulva
summer 1974	1	D-f	—	—	—	—	>400	Z. Lucas
December 1975	1	D	N	—	—	—	—	G. Forbes, Environment Canada
23 December 1976	130+	L-D	N	65m, 34f	—	—	200 - 560	Geraci and St. Aubin 1977
January 1978	1	D	W	m	—	—	~300	B. Beck, formerly DFO
autumn 1979	5+	L-D	S	—	—	—	—	H. Allison, Dartmouth, N.S.
1980	1	D	—	—	—	—	—	B. Kempton, Yarmouth, N.S.
autumn 1982	1	Ds	N	—	—	—	>400	Z. Lucas
November 1984	1	L-D	N	—	—	—	—	C. Smith, Environment Canada
May 1985	1	D	—	—	—	—	>350	J. Godsell, Waverley, N.S.
spring 1986	1	L-D	N	—	—	—	<175	S. Crowell, Barrington, N.S.
December 1989	1	D-f	W	—	—	—	—	A. MacFarlane, Environment Canada
January 1991	1	L-D	W	m	—	—	<300	W. F. DeWitt, Sackville, N.B.; R. F. Addison, DFO; necropsied for histology, organochlorine analysis
January 1992	1	D	—	—	—	—	—	Nova Scotia Stranding Network
summer 1992	4+	L-D	S	—	—	—	—	S. Oram, formerly Sable Island
23 January 1993	1	D-nf	S	—	—	sk	182	Z. Lucas
June 1993	1	D-f	N	f	—	—	>400	W. T. Stobo, DFO
21 July 1993	1	D-f	N	f	—	—	394	H. Whitehead Lab, Dalhousie University
29 July 1993	1	L	S	—	—	—	—	Z. Lucas
17 September 1993	1	D-f	N	f	—	—	184	Z. Lucas
15 December 1994	1	D	S	—	—	—	~165	A. MacFarlane
27 October 1996	1	D-nf	—	—	—	—	>350	Z. Lucas
1 November 1996	1	D-f	S	m	—	sk	~512	Z. Lucas
18 November 1996	1	L-D	N	f	—	sk	228	Z. Lucas
12 May 1997	1	D-nf	N	m	—	sk, bl	229	Z. Lucas
22 May 1997	1	D-f	S	m	✓	sk, bl	497	Z. Lucas
3 October 1997	1	D-nf	S	m	—	—	~450	Z. Lucas
18 October 1997	1	Ds	N	—	—	—	~450	Z. Lucas
18 October 1997	1	Ds	N	—	—	—	~465	Z. Lucas
22 February 1998	1	D-f	S	m	—	sk, bl	278	Z. Lucas
8 October 1998	1	D-f	S	m	✓	sk, bl	172	Z. Lucas
13 December 1998	1	D-f	N	m	✓	sk, bl, skull	183	Z. Lucas
13 December 1998	1	Ds	N	—	—	—	~590	Z. Lucas

see footnotes to Table 2

TABLE 7. Atlantic White-sided Dolphin

Date	Number	Type	Bch	Sex	Photo	Samples	Length (cm)	Source
January 1978	1	D	S	-	-	-	-	B. Beck, formerly DFO
10 September 1978	1	L	-	-	-	-	-	I. A. McLaren, Dalhousie University
November 1984	1	D	-	-	-	-	~140	Z. Lucas
5 January 1993	1	D	S	m	-	sk, bl	-	Z. Lucas
26 March 1993	5	D-f	N	5m	-	sk, m	174 - 264	Z. Lucas
20 August 1995	1	D-f	N	m	✓	-	182	Z. Lucas
29 December 1996	1	D-nf	S	m	-	sk	134	Z. Lucas
25 April 1997	1	L-D	N	m	✓	sk, bl	271	Z. Lucas
7 February 1998	1	D-f	N	m	✓	sk, bl, t	154	Z. Lucas

see footnotes to Table 2

gletons, occurred in Massachusetts (Lien and Barry 1990). The species has also recently been observed at sea in the Gully (Hooker and Baird 1999).

FAMILY – DELPHINIDAE

Long-finned Pilot Whale, *Globicephala melas*

This species was the most numerous both in number of stranding events (37) and number of individuals (> 173) on Sable (Table 6). The largest stranding recorded involved more than 130 individuals on the north side of the island in December 1976 (Geraci and St. Aubin 1977). Of the animals measured, size ranged from 200 to 560 cm, and 66% were males (Geraci and St. Aubin 1977).

There were only two other group strandings recorded, each of fewer than ten animals, one in autumn 1979, and one in summer 1992, both on the south side of the island. All three groups stranded alive. Five single strandings were of live animals and a further 11 single strandings involved individuals so freshly dead and intact that they may have died on the beach. In seven events, specimens were clearly scavenged by sharks, and were thus deemed likely to have died at sea. Those in the remaining 11 were either not fresh when found, or carcass condition was not noted, so it is not known if they came ashore as live strandings or as carcasses. Only one live stranding (a small individual found in November 1984) was obviously disabled; blood was flowing from the blowhole, and when pushed into the water by station staff, it was unable to maintain an upright position, and eventually died on the beach.

Long-finned Pilot Whales are approximately 180 cm in length at birth and are thought to mature at greater than 300 cm length (Nelson and Lien 1996). Of the 34 singleton events, lengths were measured for 25 specimens. Of these, 13 involved animals > 300 cm in length. Of these large animals, six were of known sex: four males and two females. Seven singletons were < 200 cm in length. The smallest (estimated length 140 cm from photographs) was a male found freshly dead and intact in April 1971, showing “fetal folds”. Another, also fresh and intact, found in December 1994, was

roughly 165 cm long. The five other small pilot whales, 172, 175, 182, 183 and 184 cm in length, found in October, “spring”, January, December and September, respectively, are likely to have been neonates. Jaws of the 172, 183 and 184 cm specimens were examined, and none had erupted teeth.

The 172 cm male, found in October 1998, appeared freshly dead and not scavenged. There was a small amount of chafing, suggesting that it washed ashore after death. This specimen had several long deep cuts and long score marks which together formed a large wound in a 60 cm arc on its left side from shoulder to dorsal fin. The wound was not characteristic of a shark bite (Z. Lucas, personal observation) but may have been caused by a vessel-strike. In addition, this young animal had sets of parallel rake marks (distance between marks, measured from mid-mark to mid-mark, was 10 mm) on the dorsal surface between head and dorsal fin. These marks suggested intraspecific mouthing behaviour.

In January 1991, a moribund juvenile male (<300 cm long) was found on the west tip of the island. A detailed necropsy was performed but no significant abnormalities were found; liver, heart, kidney, skin and lung tissues were submitted for histopathology, and lung samples revealed acute broncho-pneumonia (W. F. DeWitt, personal communication). Samples were collected for organochlorine analysis (R. F. Addison, personal communication), and DDT group and PCB congener data are available (# 077632, R. F. Addison).

The 15 events involving live individuals or fresh and intact carcasses, for which date of stranding is known, occurred in all months but March and August. Nine occurred in “winter” (October to March), and six occurred in “summer” (April to September). Prior to 1970 on Sable Island, there were reports of single animals dead stranded in February 1968 and January 1969, and a mass stranding of 18 live animals in October 1959, together with an observation of four other carcasses on the beach between 1967-1969 (Sergeant et al. 1970).

The Long-finned Pilot Whale, a cold-water species, mass strands in the North Atlantic from

TABLE 8. Striped Dolphin

Date	Number	Type	Beach	Sex	Photo	Samples	Length (cm)	Source
January 1985	2	D-f	S	-	-	-	-	A. MacFarlane, Environment Canada
14 December 1991	6	D-f	N	2m, 4f	-	sk*, t, fetus skin*	209 - 234	Z. Lucas (mentioned as note added in proof in Baird et al. 1993); *skin samples of 6 adults and 2 fetuses.
1 January 1992	2	D-nf	N	-	-	-	-	Z. Lucas (mentioned as note added in proof in Baird et al. 1993)
17 October 1994	6	L-D	N	-	-	-	-	G. Forbes, Environment Canada
February 1995	2	D-f	S	f, m	-	-	119, 223	Z. Lucas; P.-Y. Daoust, Atlantic Veterinary College, P.E.I.*
17 March 1995	1	D	S	m	-	-	225	Z. Lucas
18 November 1996	1	L-D	N	f	-	sk, bl	179	Z. Lucas
30 December 1998	2	D-f	S	f, m	✓	sk, bl, t, skull	212, 231	Z. Lucas

see footnotes to Table 2

*Necropsy of 119 cm female; axillary girth 63 cm; weight 118 kg; good body condition with abundant adipose tissue and normal muscle mass. Blubber thickness: dorsal 9-14 mm; lateral 10-13 mm; ventral 12 mm. Pulmonary emphysema deemed to have occurred during struggles on the beach. Stomach contents: few squid beaks, nematodes. Lumen of small intestine contained small numbers of cestodes.

Cape Cod to Newfoundland, in Greenland, and from France to Iceland (Sergeant 1982). The majority of mass strandings are in the northern part of its range north of 46°N, and Sable Island, located at 44°N, accounts for most strandings south of this latitude (Sergeant 1982). Although it has been suggested that mass strandings of this species may be increasing (Sergeant 1982; Nelson and Lien 1996), there has been only one group stranding (4+ animals) recorded on Sable Island since 1980.

Atlantic White-sided Dolphin, *Lagenorhynchus acutus*

There are records of 13 Atlantic White-sided Dolphins in nine stranding events on Sable Island (Table 7). Eight of the nine events were of singletons (two of which were alive when found), and one was a group stranding, in March 1993, of five animals found spread along one kilometer of the north beach. Sex was recorded for six of the nine events, and all, including those in the mass stranding, were males (Table 7). Of the ten specimens measured, seven were young animals < 200 cm in length. Average length at birth is considered to be 120 cm (Sergeant et al. 1980), so the 134 cm specimen may have been a suckling calf. All White-sided Dolphins came ashore during August through April; none have been recorded in May, June or July. One young male (August 1995) had numerous sets of parallel rake-marks on dorsal and flanks, possibly caused by intraspecific mouthing behaviours.

Prior to 1970 there were two records of this species on the island, a dead stranded female in January 1968 and two dead animals of unreported sex in February 1969 (Sergeant et al. 1970). Sergeant et al. (1980) suggested, on the basis of several Atlantic White-sided Dolphin mass stranding events studied, that the predominance of females and the scarcity of older immatures (between 180 to 200 cm length) in large reproductive herds indicated that immatures may lead solitary lives or may form themselves into loose social groupings, and that some mature males might remain apart in "bachelor" herds. The all-male nature of strandings reported during 1970-1998 is consistent with this hypothesis.

Gowans and Whitehead (1995) report that White-sided Dolphins are present in the Gully area during autumn, and suggested that these dolphins may be able to live year-round in the area, withstanding the cold winters. This is consistent with the Sable stranding records. Of the nine events reported here for 1970-1998 and two prior to this by Sergeant et al. (1970), eight occurred in winter.

Striped Dolphin, *Stenella coeruleoalba*

Striped Dolphins are most often found in group strandings on Sable (Table 8). Two of the records reported here (in 1991 and 1992) have previously been reported by Baird et al. (1993a). Of eight events, four involved two individuals, and two

events involved six individuals. Only two events were of single animals. In two of the eight events (those of 1994 and 1996) the dolphins were alive when found, and it is likely that the mass stranding in December 1991 involved live animals.

The six dead Striped Dolphins found in December 1991 were spread over a 50 m section of the north beach just west of the Sable Island Atmospheric Research Station. They had been scavenged by gulls, but were otherwise undamaged. Estimated length at sexual maturity is 195–220 cm for males and 216 cm for females (Baird et al. 1993a). The two males and four females were therefore likely adults (209 to 234 cm in length). The teeth of both males were worn and blunt, with some irregular in shape or broken, and several missing. Two females were pregnant, one carrying a male fetus (98 cm long) and the other a female fetus (103 cm long).

In October 1994 another stranding of six Striped Dolphins was recorded. Four adults, one immature (based on relative size) and one calf were found alive on the north beach just east of the weather station (G. Forbes, personal communication). Station staff returned all six to water, but the following morning five of the six were found dead on the same area of beach. The sixth, an adult, was not found.

Two fresh carcasses found in February 1995 were examined by P.-Y. Daoust (Atlantic Veterinary College, Prince Edward Island). The 223 cm adult male was missing all its teeth, the stomach was empty except for several squid beaks, and larval stages of tapeworms (plerocercoids) were found in the blubber and around the testicles. The 119 cm female was taken to the Atlantic Veterinary College for necropsy by P.-Y. Daoust and S. McBurney (Table 8).

Of the 22 animals, 12 were of known sex (five males, seven females), and of the 12 for which there are length data, 10 were adults > 200 cm in length. Four events occurred on the north side, and four on the south side. All eight Striped Dolphin events occurred in October through March; none during April through September. There are five reports of Striped Dolphins on Sable Island before 1970: a single dead animal in February 1964 (Mansfield 1967), a live stranding of three animals in summer 1964 and three single specimens found in January 1968 (Sergeant et al. 1970). Striped Dolphins are generally thought to prefer water temperatures > 15°C (Baird et al. 1993) and are seen in the Gully during later summer (July onwards) with the influx of warm Gulf Stream waters (Hooker et al. 1999). The autumn and winter distribution of strandings suggests that animals may remain in the area after the water has cooled. Strandings in Iceland (February) and the Faroes (December and July) were also in waters much cooler than 15°C (Bloch et al. 1996).

Killer Whale, *Orcinus orca*

The only Killer Whale in the island's records is a 590 cm male found in May 1972 (Table 9). The carcass was intact and not scavenged, with no obvious chafing of the epidermis, suggesting that the whale was alive when it came ashore or had recently died in waters near the island.

Killer Whales are only occasionally seen on the Scotian Shelf. Three Killer Whales were taken on the Scotian Shelf during the Blandford whale fishery (Mitchell and Reeves 1988). In 1992, personnel with the International Fisheries Observer Program reported four sightings: a single animal approximately 600 km east of Sable on 25 May, and between one and twenty individuals approximately 300–400 km southwest of Sable between 15 October and 4 November (J. Conway, Fisheries and Oceans Canada, personal communication). Mitchell and Reeves (1988) compiled North Atlantic Killer Whale sightings, strandings and whaling takes (from 1860–1986) and note the general paucity of records from the Scotian Shelf (9 records), compared those from Newfoundland and Labrador (> 35).

Short-beaked Common Dolphin,

Delphinus delphis

There are only four Short-beaked Common Dolphin events in the island's records and all strandings have occurred since 1996 (Table 9). One group stranding of three animals, composed of a 204 cm male and two females (170 and 199 cm long) was found in November 1996, and a 183 cm singleton of unknown sex, a 220 cm male and a 162 cm female were found in December 1997 and September and December 1998 respectively. The 1998 animals were relatively fresh and intact and may have been live strandings. Numerous cestodes were found in the 1998 male's blubber layer (> 25 in a 300 square cm section of flank blubber examined). There have been no previous records of this species stranded on Sable Island, although the species is common on the Scotian Shelf (Sergeant et al. 1970; Gowans and Whitehead 1995; Hooker et al. 1999).

White-beaked Dolphin, *Lagenorhynchus albirostris*

Only two White-beaked Dolphins stranded on Sable between 1970 and 1998 (Table 9). Both occurred on 10 March 1997, and although they were 15 km apart on the north beach, their fresh condition suggested that they comprised one stranding event. One was a 267 cm male, which had numerous teeth that were either very worn or missing. The other was a 193 cm female, which had been heavily scavenged by gulls on the beach.

Gilpin (1878) describes the characteristics of White-beaked Dolphin skulls and reports a skull fitting this description from Sable Island, providing one of the earliest reports of a stranded cetacean on Sable Island. White-beaked Dolphin sightings and strandings appear to be much more common north of

TABLE 9. Other delphinids.

Date	Species	Number	Type	Beach	Sex	Photo	Samples	Length (cm)	Source
13 May 1972	Killer Whale	1	D-f	N	m	✓	t	590	J. Boulva, DFO; tooth deposited at N.S. Natural History Museum, NSM 10783
30 March 1993	unid. dolphin	1	D-nf	S	-	-	-	244	Z. Lucas
7 January 1994	Risso's Dolphin	1	D	W	m	-	t	277	Lawson and Eddington, 1998; tooth deposited at N.S. Natural History Museum, NSM 10769
21 November 1996	Common Dolphin	3	D-f	E	1m, 2f	-	sk, bl	170-204	Z. Lucas
10 March 1997	White-beaked Dolphin	2	D-f	N	f, m	✓	sk, bl, t	193, 267	Z. Lucas
23 December 1997	Common Dolphin	1	D-nf	N	-	✓	sk, bl, t	183	Z. Lucas
7 September 1998	Common Dolphin	1	D-f	S	m	-	sk	220	Z. Lucas
24 December 1998	Common Dolphin	1	D-f	S	f	✓	sk, bl, t, skull	162	Z. Lucas

see footnotes to Table 2

TABLE 10. Harbour Porpoise.

Date	Number	Type	Beach	Sex	Photo	Samples	Length (cm)	Source.
Summer 1970	1	D	W	-	-	skull	adult	skull deposited at N.S. Natural History Museum, #971 Z.300.1
April 1972	1	D-f	-	-	-	-	~180	J. Boulva, DFO
January 1978	2	D-f	E	-	-	-	~185, 95	B. Beck, formerly DFO
June 1979	1	L-D	W	m	-	-	117	J. Parsons
May 1991	1	D-f	N	f	-	-	adult	P.S. Ross, DFO
20 January 1992	1	D	N	f	-	sk, t, skull	152	Z. Lucas
21 January 1993	1	D-f	N	m	-	sk, t, skull	112	Z. Lucas
8 February 1997	1	L-D	N	f	✓	sk, bl, t	152	Z. Lucas
24 February 1997	2	D-f	N	m, f	-	sk, bl, t, fetus skin	131, 163	Z. Lucas
26 May 1997	1	D-f	N	f	✓	sk, bl, jaw	80	Z. Lucas
8 June 1997	1	D-f	N	f	-	sk, bl	78	Z. Lucas

see footnotes to Table 2

TABLE 11. Total strandings and mass strandings (see text for definition) of species which have been observed to strand in groups. Beach and time of year of mass strandings are also shown.

Species	Total	Mass	Beach of mass stranding	Time of year of mass stranding
Sperm Whale	8	3	3N	October, January, January
Long-finned Pilot Whale	37	3	1N / 2S	December, autumn, summer
Atlantic White-sided Dolphin	9	1	1N	March
Striped Dolphin	8	2	2N	December, October
Short-beaked Common Dolphin	4	1	1E	November

Sable Island, off Newfoundland and Labrador (Alling and Whitehead 1987; Hai et al. 1996).

Risso's Dolphin, *Grampus griseus*

Only one Risso's Dolphin, a 277 cm male, has been found on Sable Island (Lawson and Eddington 1998). Photographs and teeth were collected, but researchers were not able to return to collect additional measurements until later, by which time the carcass had disappeared, either moved off the beach by the ocean overwash or buried by wind-blown sand. This report of a Risso's Dolphin was the first stranding record of the species in eastern Canada (Baird and Stacey 1991; Lawson and Eddington 1998).

FAMILY – PHOCOENIDAE

Harbour Porpoise, *Phocoena phocoena*

Thirteen Harbour Porpoises (11 records) are reported from Sable Island (Table 10), all found in late winter (January and February) and in early summer (April, May and June). None were found during July to December. Two were alive when found, and nine were fresh carcasses. A 163 cm adult female, found dead on February 24 1997, was pregnant with a male fetus 55 cm in length. Three others found dead were very small animals, 78, 80 and 95 cm in length, likely neonates. The two smallest were found, very recently dead, during late May and early June in 1997. Of the nine known-sex animals (not including the fetus), three were males (112, 117 and 131 cm in length), and six were females (78, 80, 152, 152 and 163 cm in length). The 1991 specimen was a female of reproductive age, and had an "olive-sized" blockage of the uterus, which may have been a resorbed fetus (P. S. Ross, personal communication). Average lengths of calves and immature males are 111 cm and 124 cm (Koopman 1998), and length at physical maturity is about 155 cm (Gaskin 1992), thus the two 112 and 117 cm animals were likely calves or newly weaned and the 131 cm animal an immature. Blubber thickness, measured at girth between the pectoral and dorsal fins, is available for six specimens. Two mature females (152 and 163 cm) had blubber thickness averaging 14 mm and 20 mm, respectively. These values are consistent with those reported by Koopman (1998). One imma-

ture male (131 cm) and two female calves (78 and 80 cm) had blubber averaging 7 to 10 mm, which is less than reported by Koopman (1998) for these age groups, suggesting that these three animals were in poor condition. The 112 cm male, however, had dorsal, flank and ventral blubber thicknesses of 39, 31 and 30 mm, respectively, and these values are markedly higher than those reported by Koopman (1998). Location is known for ten of the eleven Harbour Porpoise events. Of these, seven events occurred on the north beach, three on the east and west tips and none on the south side of the island. Several clean and weathered skulls of Harbour Porpoises have been found on the island additionally to these records. This suggests that this species, because of its small size, may be easily overlooked, and strandings may be more frequent than indicated by the records presented here.

Prior to 1970, a carcass of a single stranded Harbour Porpoise was reported on Sable Island in June 1961 (Mansfield 1967) and a fresh carcass was reported in January 1968 (Sergeant et al. 1970). The distribution of Harbour Porpoises is thought to extend to the edge of the Scotian Shelf (Kenney et al. 1996), but the species is rarely observed at sea around Sable Island (Hooker et al. 1999). The eleven records reported here suggest that this species distribution does extend out as far offshore as Sable Island and the species may be found fairly regularly there.

Sergeant (1982) noted that the Harbour Porpoise, a weakly social odontocete, showed a high mortality of newly weaned animals. Compared with other species reported from Sable Island during 1970-1998, relatively more Harbour Porpoises, five of 13, were very young animals.

General Trends

Mass strandings

Mass strandings observed on Sable Island between 1970 and 1998 were of Sperm Whales, Long-finned Pilot Whales, Atlantic White-sided, Short-beaked Common and Striped dolphins. Harbour Porpoise and White-beaked Dolphins have been observed to strand in pairs. Sergeant (1982) defines a "mass- or multiple stranding" as consisting of two or more animals (except the simultaneous stranding of a female

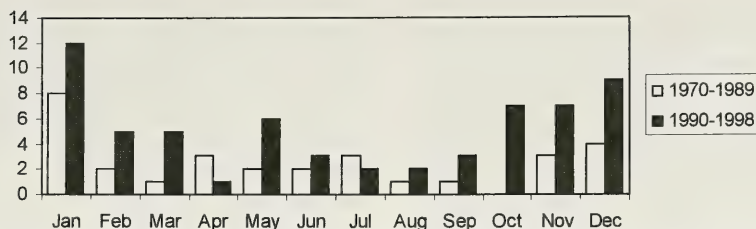


FIGURE 2. Monthly distribution of cetacean stranding events on Sable Island, shows differences between records collected incidentally 1970-1989, and those collected during more intensive monitoring 1990-1998.

and a calf, e.g., that of the Pygmy Sperm Whale reported here). Furthermore, two animals stranded at the same time but separated by some distance may not have stranded together. In fact, Sergeant (1982) noted that for Harbour Porpoise there was doubt whether animals stranded at the same time and place were in fact from the same group. There is similar doubt regarding strandings of two Harbour Porpoises (1997), two White-beaked Dolphins (1997), and two Striped Dolphins (1998) reported here. Although in each stranding the specimens were found on the same date and on the same beach, the individuals were >10 km apart. Due to the potential time-lag between the stranding and its observation, and potential interim movement of carcasses, we will exclude all strandings of two animals which were not observed stranding together from categorization as mass strandings. Therefore, although eighteen stranding events were of more than one animal, we will discuss only ten events (Table 11).

It is primarily social odontocetes which mass strand; and except for situations where the whales are trapped by ice, mysticetes do not mass strand (Sergeant 1982). Of the 12 baleen whale stranding events on Sable Island, all were single strandings, and only one was known to be alive when it came ashore (its stranding was probably caused by the severe wounds observed). Sergeant (1982) reports that while singletons may arrive on the beach dead or alive, all "mass strandings" involve live animals.

During 1970 to 1998, live whales were found in only five of the 10 mass stranding events, however most or all of the 10 events probably involved live animals coming ashore, which died prior to observation.

It has been suggested that mass stranding of odontocetes occurs at high population densities, and that mass strandings occur within the "core" of a species' range, but not at its periphery (Sergeant 1982). This would appear to be consistent with the known distribution of Sperm Whales, Pilot Whales and White-sided Dolphins (see species accounts), but Striped Dolphins are thought to be only seasonal visitors to the area.

It is interesting to note that most mass strandings occurred on the north beach or on one of the sand bars at the ends of Sable Island (Table 11). Two strandings of 4-5 pilot whales were the exception. Such a distribution of mass strandings is also consistent with the hypothesis that the sand bars projecting northwards at either end of Sable Island may act as hazards to navigation and cause mass strandings (Brabyn and McLean 1992). Between 1970-1998 there were also few group strandings during the summer months (Table 11). However, prior to 1970 Sergeant et al. (1970) described a group stranding of three Striped Dolphins during summer 1964.

Injuries/Sickness

It was not possible to determine cause of death for stranded cetaceans in most cases. Exceptions were

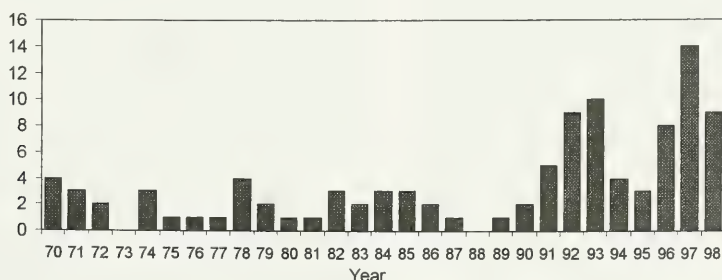


FIGURE 3. Yearly distribution of cetacean stranding events on Sable Island.

three animals which showed some evidence of external trauma, most likely caused by collision with ships: one baleen whale, the Sowerby's Beaked Whale and one Long-finned Pilot Whale (see species accounts). It was noted that a live-stranded Pilot Whale was bleeding from the blowhole, and the body cavity of a live-stranded Pygmy Sperm Whale was filled with blood, although no obvious external injuries could be seen in either specimen. Three single strandings of young Harbour Porpoises (two calves, one immature) were noted to be in poor body condition, as evidenced by very thin blubber layers. A Long-finned Pilot Whale and a Striped Dolphin were necropsied but no clear cause of stranding was found (see species accounts). Conditions such as the broncho-pneumonia in the pilot whale could have resulted from struggling and stress on the beach after stranding (W. F. DeWitt, personal communication).

Of the small number of injured or debilitated animals observed during 1970-1998, all were single strandings. Sergeant (1982) suggests that most single stranded animals are diseased or heavily parasitized, and that mass-stranded animals tend to be healthy prior to stranding. The pilot whales mass stranded in 1976 were found to be in good general body condition (Geraci and St. Aubin 1977). However, pilot whales involved in a mass stranding in Florida in 1986 exhibited histopathological changes implying that many animals' organ systems were functionally compromised prior to stranding (Bossart et al. 1991). Very few animals found on Sable Island between 1970 and 1998 were necropsied, therefore it is not possible to comment on condition of cetaceans in single versus multiple strandings.

Observations of Live Cetaceans

Strandings could be occurring from populations which utilise nearshore areas of Sable Island. Observations of live cetaceans in waters near Sable Island are relatively few. The low elevation (generally 2-4 m) of the travelled portion of the island provides a poor view of the ocean. On at least one occasion, in the early 1980s, a group (> 30) of Long-finned Pilot Whales were seen moving eastward along the north side, within 500 m of shore. These whales were accompanied by a large number of seabirds, indicating that they were feeding. In autumn 1990 station staff saw a group of > 100 Pilot Whales within 1 km of the south beach, heading east. In mid-summer of 1991 a group of eight to ten Short-beaked Common Dolphins were seen near a vessel anchored within 1 km of the north side of the island (F. Morton, personal communication). Unidentified groups of 25 to > 100 dolphins have been seen feeding within 1 to 2 km of the north side of Sable Island on three occasions, during September and November in 1997, and September 1998. On all occasions a large number of seabirds (northern gannets, shearwaters and gulls) were feeding with the

dolphins, and during the November 1997 observation the blows of at least one large baleen whale were seen in the same area as the dolphins. On 13 August 1997 one Humpback Whale was seen from an aircraft on approach to the island. The Humpback was just below the surface, within 2 km of the western tip of the island.

Other Species

Species which have not been observed stranded on Sable Island, but which have been reported in surrounding waters or stranded on mainland Nova Scotia include Bottlenose Dolphins (*Tursiops truncatus*), Right Whales (*Eubalaena glacialis*), Blainville's or Dense-beaked Whales (*Mesoplodon densirostris*), True's Beaked Whales (*Mesoplodon mirus*), Cuvier's Beaked Whales (*Ziphius cavirostris*) and Belugas (*Delphinapterus leucas*). Bottlenose Dolphins have been observed in the Gully, 30 km northeast of Sable Island (Baird et al. 1993b; Hooker et al. 1999). Right Whales have been observed as far north as Newfoundland and Labrador, and southeast Greenland (Knowlton et al. 1992), although they are more often found further south in the Bay of Fundy (Lien et al. 1989). Tracking studies have shown that Right Whales may travel widely over the Scotian Shelf (Mate et al. 1997). A True's Beaked Whale specimen was recorded from Cape Breton Island in 1938 (Allen 1939). Two Blainville's or Dense-beaked Whales have been reported: one from Peggy's Cove, Nova Scotia, in 1940 (Raven 1942) and one from Fourchu Bay, Cape Breton Island in 1968 (Sergeant et al. 1970). Houston (1991) states that Cuvier's Beaked Whales have been reported stranded from Nova Scotia to Florida, although we have been unable to locate any records from Nova Scotia. Except for an isolated population in the St. Lawrence estuary, Belugas normally inhabit arctic and subarctic waters. Occasionally, solitary or small groups of Belugas are seen along the coasts of Newfoundland, Nova Scotia and New Brunswick, and have been reported as far south as New York state (Reeves and Katona 1980; Overstrom et al. 1991). Most sightings of solitary Belugas south of the St. Lawrence estuary have been in bays and harbours, and so it is possible that Belugas would not venture offshore as far as Sable Island.

Monitoring strandings

During 1970 to 1989, the beaches were not travelled regularly and there were no personnel available to do surveys. During this period, the primary research effort (that on Grey Seals) was in January, thus causing some bias in the monthly distribution of stranding records (Figure 2). In 1990 to 1998, although January continued to be heavily monitored, there were also several research programs throughout the year which required frequent beach surveys. Comparison of records of 1970-1989 to those of

1990-1998 show fewer events were recorded during the earlier period (Figure 3): 38 in the first 20 years (1.9/year) compared with 64 in the latter nine years (7.1/year). With more frequent beach surveys, small specimens which would otherwise be washed away or washed into blowouts along the beach and buried by windblown sand, are more likely to be detected (Z. Lucas, personal observation). Larger animals remain exposed on the beach for longer periods, and are also more noticeable, and are thus more likely to be recorded.

Sable Island appears to be an excellent location for monitoring strandings of cetaceans. While mainland Nova Scotia, with over 3000 km of coastline, reported 10.8 strandings/year (Hooker et al. 1997), Sable Island which has only 80 km of coastline, had 7.1 strandings/year (recorded 1990-1998). Furthermore, the island's location allows monitoring of offshore species that might not be found further inshore. Only ten species were reported stranded in Nova Scotia between 1991-1996, compared to 15 species observed between 1990-1998 on Sable Island. These results support the conclusion of Sergeant et al. (1970) that waters around Sable Island appear to have the most diverse cetacean fauna of the region. Stranding records around the island are especially important in light of both oil and gas exploration and production in the surrounding area, and the marine protected area proposed for the Gully, the submarine canyon adjacent to Sable Island (Hooker et al. 1999).

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Gray Wolf, *Canis lupus lycaon*, Responses to Shifts of White-tailed Deer, *Odocoileus virginianus*, Adjacent to Algonquin Provincial Park, Ontario

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Changes in the distribution of White-tailed Deer (*Odocoileus virginianus*) affected the distribution of Gray Wolves (*Canis lupus lycaon*) within and adjacent to the Round Lake deer yard in central Ontario. This prompted us to re-examine the anti-predator benefits of yarding for deer. The distribution of deer and wolves in the study area, and locations of deer kills were documented in four periods over the winter. Road and forest deer track counts, infrared monitoring at deer migration routes, and wolf radio tracking techniques were the main methods employed. As snow depth increased, deer distribution changed from a loose aggregation in late January to a more clumped distribution in March. Three wolf packs had their territories partially or fully within the deer yard and 13 radio-collared migratory wolves and their pack mates in seven packs, left their territories in the park and followed the deer to the concentration area, resulting in a high density of wolves during the winter. The majority of wolves responded to the shifting deer distribution by staying in areas of high deer density within the yard and its periphery, and 21 of 27 kill-sites found were located in these areas. The loose aggregation of mostly small deer groups in the Round Lake deer yard meant that enhanced predator detection as well as increased confusion of the predator during an attack presumably were minor factors contributing to greater safety in the yard. As a result of the aggregation of migratory and resident wolves in the yard, the ratio of predator to prey was not lowered as it may be in other cases. Except for the possibility of enhanced escape using the trail network, there appears to be little evidence for anti-predator benefits of yarding for deer in the Round Lake deer yard.

Key Words: White-tailed Deer, *Odocoileus virginianus*, deer yard, Gray Wolf, *Canis lupus lycaon*, anti-predator strategy, Ontario.

Seasonal migration to winter deer yards by White-tailed Deer (*Odocoileus virginianus*) is well known where snow depths inhibit movements (Halls 1978). Coniferous cover of yards provides shelter from wind and snow, and hence decreases locomotive costs and enhances energetic efficiency (Ozoga 1968; Blouch 1984). Yarding behaviour has also been proposed as an anti-predator response with various benefits including enhanced predator detection, escape via the trail system, and prey dilution (Nelson and Mech 1981; Messier and Barrette 1985).

A deer migration from approximately 2500 km² of summer range in eastern Algonquin Provincial Park to one major wintering yard induces up to twelve resident Gray Wolf (*Canis lupus lycaon*) packs to temporarily leave their territories and migrate and concentrate with the deer each winter (Forbes and Theberge 1995). In addition to the presence of migratory wolves in the yard during winter, three wolf packs had their territories entirely or partially within the yard or its close proximity year-round. The extensiveness of this migratory wolf concentration at a White-tailed Deer winter aggregation is exceptional (Forbes and Theberge 1995), and provided an opportunity to study wolf-deer spatial and foraging relationships, and re-examine the benefits

of yarding as a predator defence. We studied shifts in winter deer distribution in the yard and accompanying changes in wolf distribution based upon 14 radio-collared wolves in ten packs and three solitary radio-tagged wolves.

Study Area and Prey Base

The study was conducted from December 1996 until May 1997 in the Round Lake deer yard (45° 35' N, 77° 30' W) and its immediate periphery, adjacent to Algonquin Provincial Park in central Ontario. The study area covers a total of approximately 300 km² and its core, the yard, where most deer congregate especially in late winter, is approximately 80 km² (Forbes and Theberge 1995). Both the core and the periphery are of importance for the ecology of wolves and deer during different stages of the winter as studies in the Round Lake deer yard and its periphery in previous winters have shown.

The study area consists of a heterogeneous mix of patches of forested, cleared, and settled land. Forested areas cover about 70% of the study area; the dominant tree species are common to both the Deciduous and the Boreal Forest Regions (Rowe 1972) and include White Pine (*Pinus strobus*), Red Pine (*Pinus resinosa*) and Jack Pine (*Pinus*

banksiana), mixed with Red Maple (*Acer rubrum*), Large-tooth Aspen (*Populus grandidentata*) and Trembling Aspen (*Populus tremuloides*). Pine plantations are scattered throughout the area. Low elevation areas, mainly in the core of the study area, contain boreal species such as Eastern White Cedar (*Thuja occidentalis*), Black Spruce (*Picea mariana*), and Balsam Fir (*Abies balsamea*). Dominant deciduous tree species on the hills and slopes of the yard are Sugar Maple (*Acer saccharum*), and Red Maple (*Acer rubrum*). Hills in the yard periphery have a significant component of Red Oak (*Quercus rubra*), Eastern Hemlock (*Tsuga canadensis*), and Beech (*Fagus grandifolia*). Four villages are situated in or around the perimeter of the yard, and farms and houses are found along a grid of concession roads throughout. Elevation ranges from 180 to 300 m above sea level, which constitutes a drop of at least 280 m from the Algonquin Dome to the west. The area has a low mean annual precipitation of 66 cm of which 15 to 30% occurs as snowfall (Brown et al. 1968). The average January temperature is -12.5°C , although minimum temperatures of -40°C are possible (Environment Canada 1993). The winter of 1996–97 was considered severe for deer according to the Ontario Winter Severity Index (Ontario Ministry of Natural Resources, Pembroke District and Wildlife Policy Branch, unpublished data).

Algonquin wolves feed on three large prey species: Moose (*Alces alces*), White-tailed Deer, and Beaver (*Castor canadensis*), but deer are the preferred winter prey species, as shown by the influence of their annual migration to wintering areas outside the park on wolf movements (Forbes and Theberge 1995). Depending in part on the number of deer over-wintering in the park, a variable number of wolves travel to these yards. Aerial surveys and observations, and ground searches in the winters of 1987 through 1995 showed that no or few deer (60 to 100) in the winters of 1988–89, 1989–90, 1993–94 and 1994–95) stayed in the park (Swanson 1993; Forbes and Theberge 1995; Cook 1996). Based on observations from wolf aerial work, no deer were believed to be present in the 2500 km² park area drained by the deer migration during this study (winter of 1996–1997). Swanson (1993) estimated that 1500 to 2500 deer congregated in the Round Lake deer yard in the winters of 1990–1991 and 1991–1992. Two smaller yards (Black Bay, located 15 km east of Algonquin Park, and Germanicus, approximately 20 km to the east of the Round Lake deer yard) each supported an additional 500 animals.

Methods

Deer arrival and departure, and distribution in the yard

The timing of deer movement to and from the winter yards was investigated using electronic

infrared game monitoring units ("Trail Master", Goodson and Associates Incorporated, Kansas) set up at three major deer crossings of waterways or a highway in the northern yard periphery before deer entered the yarding areas. One of these crossings was used by deer moving to the Germanicus deer yard, and its monitoring was included in the study design because of its proximity to the Round Lake deer yard, and its influence on movements of wolves. Monitors were read once a week in the early afternoon, and deer track counts were conducted along the whole length of the crossings for comparison with the monitor results.

Deer distribution and relative abundance within the study area were obtained from track counts on a systematic grid of 34 roads and spurs totalling 153.9 km. All roads suitable for road counts (no major traffic, no use of road salt) were included in this grid. In addition, tracks were counted along 27 defined strip transects (250 m \times 2 m) in forested locations. Transects and roads were covered approximately twice a month beginning in January. Elapsed time from the last snowfall, ploughing, high winds, or rainfall ranged from 20 to 60 hours. Between 9 January and 8 April 1997, deer tracks were counted on 784.1 km of roads and spurs and on 30.0 km of transects in the Round Lake deer yard and its periphery.

Road counts were made on one side of the road or spur by an observer in a vehicle in slow motion (≤ 20 km/h), similar to Mooty and Karns (1984). Sets of tracks were summed up for every 500 m of road. Where road length could not be divided into 500 m-sections, tracks per 100 m were adjusted accordingly. Deer runways across the road or transect were assigned a number of track sets according to the size of the runway to account for heavy (50 sets), intermediate (20 sets), or marginal use (5 sets). These values represent the estimated minimum values for the three defined categories. Tracks of deer travelling down roads or criss-crossing the transect were included only once in the count. All deer seen were recorded.

Transects were chosen to represent major habitat types: open deciduous or mixed deciduous-coniferous forest in the yard periphery, open deciduous or mixed deciduous-coniferous forest in the yard, and closed coniferous forest in the yard. Crown closure was estimated visually as "closed" ($>70\%$ crown closure), "open" (40–70% crown closure), or "other" ($<40\%$ crown closure). Snow depths were measured at the start and end of all transects using a metal meter-stick and averaged for each habitat type in the yard periphery or yard for each period (see Methods: Mapping of wolf and deer distribution, and deer kills).

Hourly ambient air temperature in the yard was recorded from 9 January to 16 May 1997, using a data logger (Squirrel meter/logger type SQ8-IU/3V3-SP, Grant Instruments Ltd., Cambridge,

England). Additional temperature data (daily maximum, minimum, and mean) were obtained from Environment Canada for comparison. Wind chill, and additional snow depth and crust measurements for the area were provided by the Pembroke District and Wildlife Policy Branch of the Ontario Ministry of Natural Resources. Windchill was measured with the use of a chillometre (Verme 1968) between 4 November and 1 April, ranging between 0 and 9.6 kilowatts per hour — amount of energy necessary to maintain water at four degrees C (Smith et al. 1989).

Wolf distribution

The distribution of wolves was determined by aerial and ground telemetry. Sightings, tracks, scats, and howling provided additional information. Wolves had been live-captured and radio-collared in previous summer field seasons. Methods for capture were described by Forbes and Theberge (1995). With the exception of four packs (Byers Creek, Basin, Jocko and McDonald), all study packs were represented by only one radio-collared wolf.

Radio-collared wolves were located by means of ground and aerial telemetry with portable receiver-scanners (Lotek Engineering, Newmarket, Ontario; Advanced Telemetry Systems Incorporated, Isanti, Minnesota). Between 9 January and 8 April, 410 independent wolf locations were collected. An additional 60 independent fixes were also collected before and after this time span (35 before, 25 after). Number of telemetry flights varied from two to seven during periods (19 flights in total). Ground telemetry was used to cover the entire study area at least every second day. Data were plotted using the Universal Transverse Mercator (UTM) 100 m \times 100 m-grid on 1 : 50 000 topographic maps.

Deer kills

Deer kill-sites were located by aerial and ground reconnaissance, primarily during wolf telemetry searches. Search effort was consistent between areas of different deer densities and among the four periods. Kills were confirmed by ground observations to exclude the possibility that wolves were only scavenging. Evidence that a deer had been killed by wolves included signs of a chase in the snow, broken vegetation, and/or scattered blood which had likely resulted from a chase or struggle. In contrast, when wolves scavenge on a frozen carcass, the remains are usually less scattered (Haynes 1982).

Three 250 m \times 2 m-deer track transects were walked, forming a triangle around each kill-site. On the basis that most chases of deer are short (Nelson and Mech 1991; Paquet 1992), we considered the site of the kill to be representative of local deer density for our triangular track counts. The number of track sets encountered on the three 250 m-stretches at each kill-site were averaged and included in the mapping of deer density areas. The number of wolves involved in the kill was established using a

combination of aerial observation, radio-tracking, howling, and number of track sets encountered at the kill-site.

Mapping of wolf and deer distribution, and deer kills

Four 22 day-long periods accommodating natural breakpoints in deer movement and distribution in the study area were defined in order to compare wolf distribution with deer shifts during the winter. *Period 1: 9 January – 30 January 1997* started with the migration peak at the deer crossings and included the weeks when deer were entering the yards in large numbers. *Period 2: 31 January – 21 February 1997* covered the days when deer were entering the yards in declining numbers, until the complete end of migration. *Period 3: 22 February – 15 March 1997* included the weeks when deer had all congregated in the Round Lake deer yard. *Period 4: 16 March – 8 April 1997 (excluding 6 and 7 April)* covered the second half of the phase of deer concentration, when the deer restricted their movement to a smaller area in the yard. Since periods were designated after the end of the field season, not all periods include a count on each road and transect. If two or more counts on the same road or transect fell into one period, the number of deer track sets was averaged.

Results of road, transect and kill-site track counts in the yard and its periphery were combined for each period. Three deer density categories were defined: nil, low (< 2.0 sets of tracks/100 m) and high (≥ 2.0 sets of tracks/100 m). These categories were established arbitrarily based on the range observed. The category "nil" does not exclude the possibility of occasional, unnoticed deer tracks on roads and transects. The median of all track counts for all transects ($n = 120$) was 1.2, the first and third quartiles 0 and 4.8, respectively, and the range 0 to 30.8 sets of tracks per 100 m.

Track counts from the designated periods were mapped and the locations of radio-collared wolves superimposed on the image of deer distribution using the raster-based geographic information system SPatial ANalysis Systems (SPANS Explorer and Topographer, Tydac Technologies Incorporated, Nepean, Ontario, 1996, 1997). Images of deer densities were generated using the contour function with a quad level of approximately 200 m, and afterwards a smoothing function, to digitally represent the point data as a continuous surface. Contouring uses boundaries to connect points with identical values (Burke 1996). The point of location for each road count section or transect was placed midway on the section or transect. Since transects and road sections were of different length, the number of deer track sets per 100 m was calculated in order to combine all deer track data. Availability of areas of nil, low and high deer density in the study area (in km²) during each period was obtained from the deer coverages generated in SPANS. The number of expected wolf loca-

tions in each deer density category and period was determined by using the ratio between areas of nil, low and high deer density areas. The number of wolf fixes that actually fell on each density classification was recorded for each wolf and then combined for results of only migratory wolves or combined migratory and resident wolves.

A Chi-square test for goodness-of-fit was used to test whether wolves spent significantly more time in high deer density areas than in areas of nil or low deer density. To ensure independence of telemetry locations for radio-collared wolves in the study area, an interval of four hours had to elapse between two telemetry fixes for an individual wolf. If several locations had been obtained for one wolf over a period of four hours, only the first one was included in the analysis. This procedure follows the general rule outlined in White and Garrott (1990), that two locations can be considered statistically independent if sufficient time has elapsed for the animal to move from one end of the study area to the other. Since the study area measured only approximately 300 km², and the extreme longest straight distance was less than 30 km, a wolf would be able to move from one end of the study area to the other in four hours. Mech (1994) thought a pace of 8.7 km/h to be representative for general travel of wolves on trails, lakes, roads, and other open terrain as was the case in our study area. The Chi-square analysis was based on the following: (1) the total number of telemetry fixes observed in each deer density category for each period (total results of all collared wolves), and (2) the total number of fixes for park wolves only in each deer density category for each period. If two radio-collared wolves of the same pack were in the same location, only one fix was included in the total for the Chi-square analysis. In addition, a Chi-square test for goodness-of-fit was performed on the number of deer kills found in areas of low and high deer density to test if wolves made significantly more kills in areas of high prey density than in areas of lower prey density.

Results

Deer and wolf distribution

In December, the majority of deer made use of oak-dominated forests in the north of the study area, where an average snow depth of 13.8 cm and the lack of a crust made digging for acorns easy. Deer moved into the yard in three waves over a period of seven weeks between the end of December and mid February. A few individuals entered the yard after a drop in temperature to -20° C (Environment Canada, Petawawa climatic station, unpublished data) in combination with the reaching of a weekly wind chill of 4 kWh at the end of December (Ontario Ministry of Natural Resources, Pembroke District and Wildlife Policy Branch, unpublished data). Approximately 70% of the deer moved to the Round Lake wintering area between 7 January and 27 January, with a peak on 8 January, after the formation of a snow crust due to freezing rain on 4 January which apparently aggravated foraging. Snow depth had increased to 20 cm in the yard periphery by 6 January (Ontario Ministry of Natural Resources, Pembroke District and Wildlife Policy Branch, unpublished data). The remaining deer entered the yard with increasing snow depth between 28 January and 15 February.

Over the four periods, deer shifted from northern to eastern, and then to southern portions of the study area. In periods 2, 3 and 4, heaviest deer use was in areas with shallowest snow conditions (Table 1). All deer that moved towards the Round Lake Deer Yard had congregated in the yard by the end of time period 2 (Figure 2). In late winter, deer concentrated to a greater extent, with the areas of high density shrinking (Figure 4). Eighty-four percent of a total of 230 deer sightings during the winter involved single animals, or groups of two or three. Groups of four or more animals were mainly seen around feeding stations near human habitation or cut browse. These locations were found in the whole study area, but mainly located in the centre of the yard.

During the winter, three radio-collared solitary wolves and ten radio-tagged wolves from seven

TABLE 1. Changes in mean snow depth for deer track transects by time period (TP) in various habitats within the Round Lake deer yard and its periphery.

Area and Forest Cover	Mean Snow Depth			
	TP 1	TP 2	TP 3	TP 4
Open Deciduous or Mixed Deciduous-Coniferous Forest in Yard Periphery	31.3 ± 3.6 cm¹ (6)²	51.2 ± 2.5 cm (7)	68.0 ± 5.6 cm (4)	71.3 ± 9.8 cm (3)
Open Deciduous or Mixed Deciduous-Coniferous Forest in Yard	28.6 ± 3.0 cm (4)	41.9 ± 2.1 cm (6)	55.4 ± 4.6 cm (6)	61.3 ± 7.8 cm (6)
Closed Coniferous Forest in Yard	16.1 ± 1.3 cm (10)	33.2 ± 2.1 cm (10)	32.0 ± 3.0 cm (10)	24.3 ± 4.4 cm (10)

¹Bold numbers refer to average snow depths with standard errors of habitats where the majority of deer were located in each period.
²Number of transects.

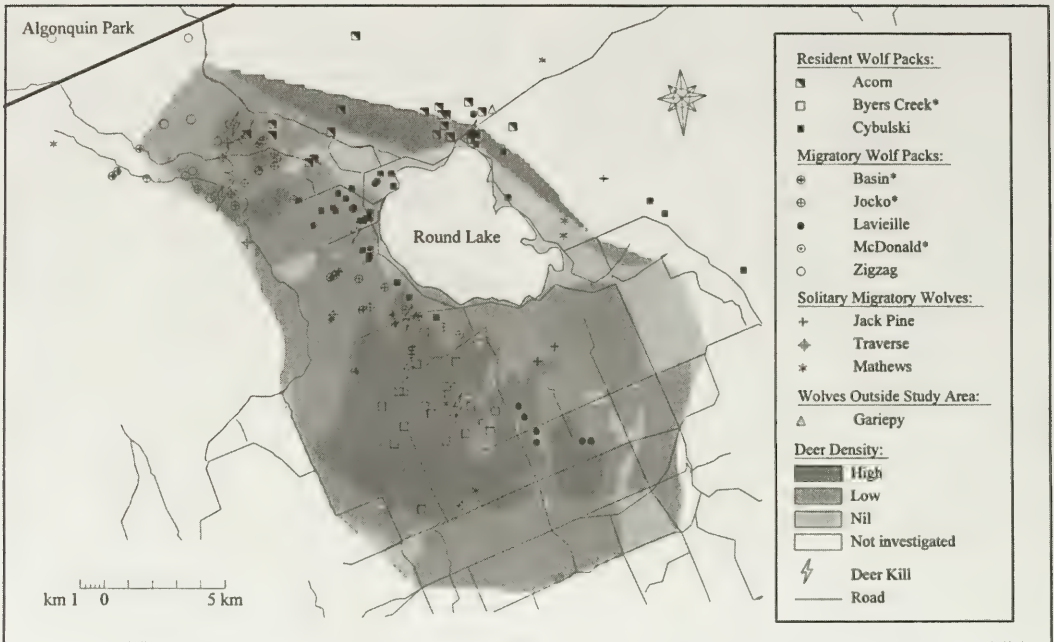


FIGURE 1. Locations of radio-collared wolves and deer kills in relation to deer distribution in the study area for period 1 (9–30 January 1997). Low deer density < 2.0 sets of tracks/100 m, high deer density \geq 2.0 sets of tracks/100 m. A * identifies packs with two radio-collared wolves. No rivers and only selected roads are shown.

packs with territories in the park travelled to the Round Lake deer yard. Throughout the winter, four of these packs — Basin, Hardwood, Lavieille, and McDonald — each only had two pack members. The Jocko and Zigzag packs were larger with six and nine wolves, respectively, although the Zigzag pack split as of mid-February. The radio-collared Zigzag wolf was with four wolves afterwards. In addition, three year-round resident packs with a total of four radio-collared wolves had their territories partially or fully within the yard (Acorn pack: four members, Byers Creek: three, Cybulski: two). The radio-collared wolf of the Cybulski pack died as a result of a vehicle collision in early February.

The number of wolves in the Round Lake deer yard varied among the four periods, being highest between 31 January and 21 February (period 2, Figure 2), and lowest between 16 March and 8 April (period 4, Figure 4). During period 1 (Figure 1), most migratory wolves made use of the yard periphery. The number of fixes in the periphery decreased in the following time periods, when wolves shifted their locations to the core of the study area (Figures 2 to 4). None of the radio-collared migratory wolves stayed in the Round Lake deer yard throughout the whole winter; aerial telemetry indicated that they occasionally travelled back to their territories in the park. Two migratory packs, Jocko and McDonald, returned to their territories in mid February after the end of the deer migra-

tion to the yards. Before deer entered the wintering area, only one park wolf, with one other wolf, was found in the Round Lake deer yard.

In all four periods, Chi-square analysis showed that wolves (both migratory and combined resident and migratory) selected areas of high deer density (Table 2). A few individual packs deviated from this relationship, as was the case, for example, with the resident Cybulski pack in period 1, the resident Acorn pack in time periods 2 to 4, the Zigzag pack in period 2, and the Basin pack in periods 3 and 4. During the entire field season, radio-collared wolves of the resident Acorn and resident Byers Creek packs did not shift from, but only adjusted to changes in deer distribution within their territories. Most of the Byers Creek territory held large numbers of deer throughout the winter, while the Acorn territory received most of the deer during the migration to and from the yard. In contrast, the radio-collared Cybulski wolf left her territory several times to travel east or south into areas of high deer density. The Cybulski territory experienced nil or low deer density during the winter. While migratory packs were more sedentary and generally remained in one area for a few days before moving on, solitary migratory wolves seldom stayed in one location for more than two consecutive days.

During mid to late April, when deer were moving back to their summer ranges, only three radio-collared

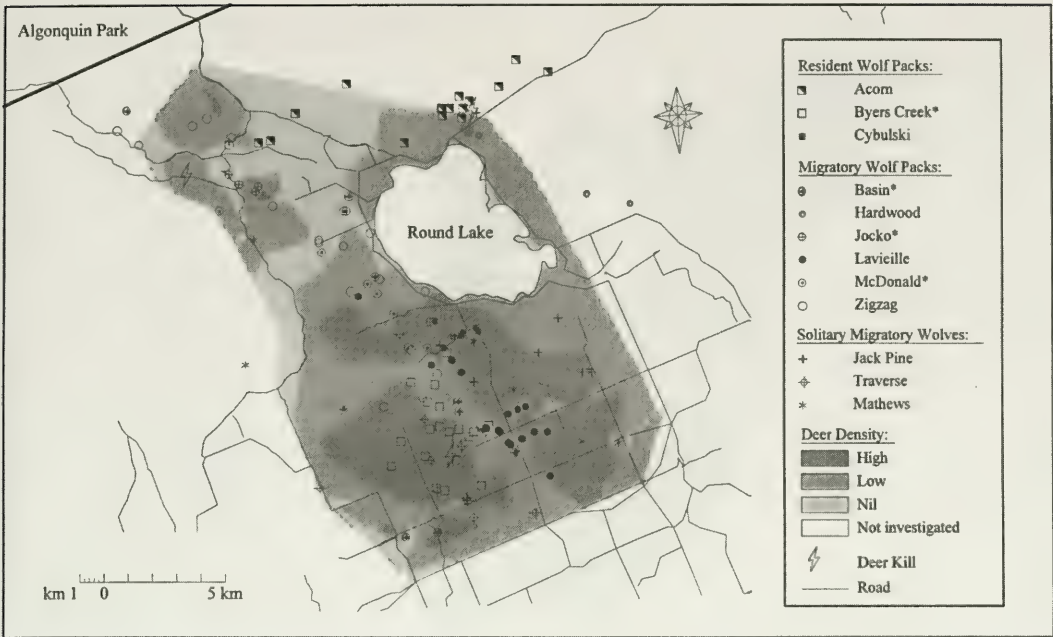


FIGURE 2. Locations of radio-collared wolves and deer kills in relation to deer distribution in the study area for period 2 (31 January–21 February 1997). Low deer density < 2.0 sets of tracks/100 m, high deer density ≥ 2.0 sets of tracks/100 m. A * identifies packs with two radio-collared wolves. No rivers and only selected roads are shown.

wolves from two migratory packs (Basin, Zigzag), and one radio-equipped solitary park wolf (Traverse) were located in the study area. Deer departure was apparently influenced by decreasing snow depth and indirectly by daily mean temperatures above 0°C melting the snow. After 14 April, average daily temperatures were constantly above 0°C and minimum daily temperatures were rarely below freezing (Environment Canada, Petawawa climatic station, unpublished data). Snow had melted to a great extent (> 50%) on most transects. The weekly wind chill was measured at 3.4 kWh on 14 April (Ontario Ministry of Natural Resources, Pembroke District and Wildlife Policy Branch, unpublished data).

Deer kills

Of 29 kills found during the winter, one kill was made at the end of December before the deer movement reached its peak at the deer crossings, seven took place during the period when the majority of deer entered the yard (Figure 1), three occurred during the second half of the final deer movement to the yard (Figure 2), twelve between 22 February and 15 March when deer were more or less stationary (Figure 3), and six during the time of maximum deer concentration in late March (Figure 4). Chi-square analysis showed that deer kills were made significantly more often in areas of high deer density ($n = 21$) than in low density ($n = 6$) ($\chi^2 = 7.26$, 1 df, $p < 0.01$, $n = 27$). These results include kills of

migratory deer that were entering the yard and one deer kill which was found outside, but close to the study area; excluding these kills gave similar results ($\chi^2 = 10.23$, 1 df, $p < 0.01$, $n = 22$). Eleven out of twelve chases were short, and ranged from 10 to 70 m. One chase was over 1 km long but private property hindered our ability to follow the tracks to the start location. It was not possible to reconstruct the chases for the remaining 17 kills.

Discussion

Our evidence indicates that White-tailed Deer moved into the Round Lake deer yard in response to temperature in combination with wind chill, snow depth and crust, as found in other North American studies (Ozoga and Gysel 1972; Nelson 1995; Broadfoot and Voigt 1996). Migratory wolf packs abandoned their summer territories to concentrate in areas of migratory deer aggregations. While others have found that wolf packs may adjust their movements within their territories when deer concentrate within them (Van Ballenberghe et al. 1975; Fritts and Mech 1981; and Fuller 1991 for Minnesota; and Potvin 1988 for Quebec), in this study we found that migratory wolves abandoned their normal territories over a large area to converge on the wintering deer for extended periods.

Subsequently, as winter progressed, deer shifted their distribution within the yard in response to snow



FIGURE 3. Locations of radio-collared wolves and deer kills in relation to deer distribution in the study area for period 3 (22 February–15 March 1997). Low deer density < 2.0 sets of tracks/100 m, high deer density ≥ 2.0 sets of tracks/100 m. A * identifies packs with two radio-collared wolves. No rivers and only selected roads are shown.

depth, and primarily made use of conifer dominated forests with dense canopies which may serve to reduce energy expenditures due to locomotion and thermoregulation (e.g., Ozoga 1968; Telfer 1970; Ozoga and Gysel 1972; Drolet 1976). The migratory wolves quickly detected and disproportionately hunted deer in areas of highest deer concentration, first as deer funnelled into the yard in its periphery, then in the yard. Distance and duration of winter extraterritorial movements of park wolves were highly variable, as has been described before (Forbes and Theberge 1995). All-season resident wolves with all or parts of their territories within the yard adjusted to changes in deer distribution only within their territories, except for one wolf which left its territory when it was devoid or almost devoid of deer.

When wolf packs have access to a range of wintering deer densities within their territories, some authors have suggested that wolves hunt primarily in areas of high deer density (Van Ballenberghe et al. 1975; Potvin 1988), while other authors have found the reverse. Fritts and Mech (1981) found that all packs in their study were frequently located in the vicinity of deer yards, however, areas of high deer density were used little and only few deer kills were found there. Another study in Minnesota found that wolves rarely visited deer yards (Hoskinson and Mech 1976). In Ontario, Kolenosky (1972) reported that predation was disproportionately heavier in deer

pockets outside the main yard where the deer density was lower than in the core of the yard. Messier and Barrette (1985) found that pairs and packs of Coyotes (*Canis latrans*) in Quebec were located more often in areas of low deer density where only 12% of the over-wintering deer congregated.

Differences reported by these authors may relate to differences in absolute deer densities, categorised differently by various authors, or possibly different methods used to assess deer abundance. A comparison of results between studies was not always possible since some authors did not mention how deer density had been partitioned into categories (Kolenosky 1972; Fritts and Mech 1981). Our study differed from all of them, however, because it involved migratory wolves at times reaching densities in excess of one per 10 km², in addition to resident wolves. As well, yards in most studies are considerably smaller than the Round Lake deer yard (Van Ballenberghe et al. 1975; Hoskinson and Mech 1976; Fritts and Mech 1981; Nelson and Mech 1981), and many yards were located within the territory of one wolf pack or along territory edges between packs (Hoskinson and Mech 1976; Fritts and Mech 1981; Nelson and Mech 1981).

Messier and Barrette (1985) and Parker and Maxwell (1989) who studied Coyotes in Quebec and northern New Brunswick, respectively, felt that Coyote territorial behaviour discourages an aggrega-

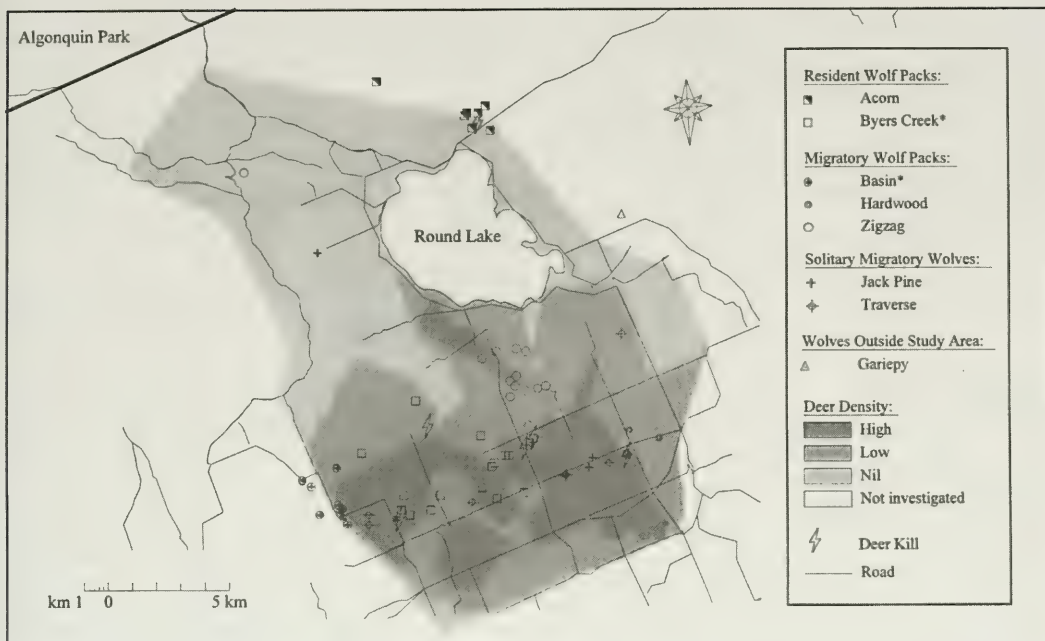


FIGURE 4. Locations of radio-collared wolves and deer kills in relation to deer distribution in the study area for period 4 (16 March–8 April 1997). Low deer density < 2.0 sets of tracks/100 m, high deer density \geq 2.0 sets of tracks/100 m. A * identifies packs with two radio-collared wolves. No rivers and only selected roads are shown.

tion of Coyotes in winter deer concentration areas. The high wolf density in the Round Lake deer yard (Forbes and Theberge 1995) and the reported little intraspecific aggression between wolves occupying the yard during the winter (Cook 1996; Theberge 1998) indicate that Algonquin wolves exhibit high tolerance levels.

It has been argued that yarding of deer might have evolved as an anti-predator strategy (Nelson and Mech 1981; Messier and Barrette 1985; Nelson and Mech 1991). Nelson and Mech (1981, 1986) observed that White-tailed Deer are much more vulnerable to wolf predation in winter because of impediment by snow and reduced energy reserves. To minimise vulnerability, deer may concentrate in relatively small areas. Nelson and Mech (1981) suggested six benefits of deer concentration. Under winter conditions, safety in numbers exists because grouping (1) facilitates the formation of a well-worn trail network that can be used for escape routes, (2) increases deer ability to detect predators, (3) improves ability to confuse predators, (4) results in lower ratios of predator to prey (dilution factor), (5) increases time for foraging and ruminating because of decreased vigilance time, and (6) increases exposure of more vulnerable older deer and hence improves survival chances for younger deer of the population.

Our observations that most deer were in small (<4 deer), and dispersed groups, an observation also

made by others (Hoskinson and Mech 1976), discounts reasons 2, 3 and 5. Fryxell (1991) also questioned the benefits of aggregation and suggested that loose aggregation of herbivores over a large area, in contrast to a single cohesive group, might only have the advantage of the dilution of the risk of an attack. Carbyn et al. (1993) described a scenario where bison were likely more vulnerable in areas of concentration than in areas where the herds were smaller and dispersed. The results of a study of yarded and non-yarded deer in New Brunswick (Whitlaw et al. 1998) also do not support the hypothesis of yarding as an anti-predator strategy. The high wolf densities caused by migratory wolves (Forbes and Theberge 1995), and the apparent high tolerance levels among wolves in the yard negate the dilution factor (reason 4). Our observations that deer pursued by wolves typically plunge away in panic, irrespective of deer trails, weakens reason 1. Reason 6 differs from the others in not explaining an individual benefit of yarding, rather, it refers to selection of age group only. We conclude that in our study, deer not only did not obtain any significant anti-predator benefit from yarding, but because of reduced wolf search time, especially at concentration areas in the yard periphery when deer entered the yard, may have been more vulnerable. This conclusion may suggest that natural selection would work against yarding behaviour. However, scattered deer that failed to

TABLE 2. Observed versus expected number of fixes for migratory radio-collared and all radio-collared wolves located in areas of deer absence, low and high deer density in the study area. In cases in which two radio-collared wolves of the same pack were in the same location, only one fix for both wolves was included in the summary. Results of the Chi-square test for goodness of fit are given in footnotes.

Time Period Wolves	Deer Absence		Low Deer Density		High Deer Density		Total Number of Fixes
	Observed	Expected ^E	Observed	Expected	Observed	Expected	
9 January – 30 January 1997							
Total of All Wolves ^T	9 (6.7)*	22.2 (16.6)	53 (39.6)	71.7 (53.5)	72 (53.7)	40.1 (29.9)	134 (100) ^a
Total of All Migratory Wolves ^M	3 (4.4)	11.3 (16.6)	24 (35.3)	36.4 (53.5)	41 (60.3)	20.3 (29.9)	68 (100) ^b
31 January – 21 February 1997							
Total of All Wolves ^T	17 (14.2)	25.9 (21.6)	50 (41.7)	60.7 (50.6)	53 (44.2)	33.4 (27.8)	120 (100) ^c
Total of All Migratory Wolves ^M	12 (14.0)	18.6 (21.6)	40 (46.5)	43.5 (50.6)	34 (39.5)	23.9 (27.8)	86 (100) ^d
22 February – 15 March 1997							
Total of All Wolves ^T	21 (20.6)	42.1 (41.3)	29 (28.4)	30.1 (29.5)	52 (51.0)	29.8 (29.2)	102 (100) ^e
Total of All Migratory Wolves ^M	18 (24.3)	30.6 (41.3)	20 (27.0)	21.8 (29.5)	36 (48.6)	21.6 (29.2)	74 (100) ^f
16 March – 8 April 1997							
Total of All Wolves ^T	4 (7.4)	25.9 (48.0)	25 (46.3)	18.1 (33.6)	25 (46.3)	10.0 (18.5)	54 (100) ^g
Total of All Migratory Wolves ^M	2 (5.6)	17.3 (48.0)	18 (50.0)	12.1 (33.6)	16 (44.4)	6.7 (18.5)	36 (100) ^h

^EExpected number of wolf locations was calculated from the availability of different areas of deer density in the study area (see methods for details).

*9 (6.7); 9 refers to the number of fixes for the wolves; 6.7 represents the percentage of wolf fixes in the nil deer density category.

^TThe total includes only one fix for occasions when two radio-collared wolves of the same pack were in the same location.

^MThe total of all migratory wolves includes only fixes for wolves which have their summer territory in Algonquin Provincial Park. This total includes only one fix for occasions when two radio-collared members of the same pack were in the same location.

^a $\chi^2 = 38.10$, 2 df, $p \leq 0.001$ ^c $\chi^2 = 16.45$, 2 df, $p < 0.001$ ^e $\chi^2 = 27.15$, 2 df, $p < 0.001$ ^g $\chi^2 = 43.65$, 2 df, $p < 0.001$

^b $\chi^2 = 31.43$, 2 df, $p < 0.001$ ^d $\chi^2 = 6.89$, 2 df, $p < 0.05$ ^f $\chi^2 = 14.94$, 2 df, $p < 0.001$ ^h $\chi^2 = 53.58$, 2 df, $p < 0.001$

migrate in previous winters were highly vulnerable to wolves when packs returned periodically to their territories (Forbes and Theberge 1996). Deer in this system appear to make the decision whether or not to migrate based on proximal environmental conditions — snow, temperature, wind chill — and move within the wintering yard irrespective of their susceptibility to predation.

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Breeding Atlantic Puffins, *Fratercula arctica*, and Other Bird Species of Coburg Island, Nunavut

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Coburg Island and neighbouring waters were recently designated a Canadian National Wildlife Area. The large seabird colony at Cambridge Point has been previously described, and is dominated by Thick-billed Murres (160 000 pairs). We found that a small offshore island, named Princess Charlotte Monument, also supported breeding populations of seven marine bird species; three of which did not breed at the main colony (i.e., Northern Fulmar, Common Eider, and Atlantic Puffin). This is the most northern confirmed breeding site for Atlantic Puffins in Canada. Puffins at both Coburg Island and northern Greenland nest in rock crevices, apparently because permafrost in soil prevents burrow nesting. We suggest that puffin populations in the high arctic may be limited by habitat, rather than prey availability.

Key Words: Atlantic Puffin, *Fratercula arctica*, Coburg Island, Northwater Polynya, breeding range, Nunavut, Canada.

Polynyas are areas of open water in the arctic that occur when much of the ocean is otherwise covered in ice. In general, polynyas are highly productive and provide foraging habitat for many marine mammal and seabird species (Stirling 1997; Falk and Moller 1995; Falk et al. 1997). Coburg Island is located on the west margin of the Northwater Polynya (Figure 1), and supports one of the largest seabird colonies in the Canadian Arctic (Birkhead and Nettleship 1981). It was protected as a National Wildlife Area (NWA) in 1995 in recognition of its biological importance (Nirjutiqavvik NWA).

Coburg Island is a very significant seabird colony in Canada's high Arctic. Approximately 160 000 pairs of Thick-billed Murres, *Uria lomvia*, and 30 000 pairs of Black-legged Kittiwakes, *Rissa tridactyla*, nest along 6 km of coastline north of Cambridge Point (Birkhead and Nettleship 1981; Figure 2). A second, previously undescribed, colony exists on a rock tower named Princess Charlotte Monument 15 km east of the main colony. Here, we report the bird species observed between Cambridge Point and the Marina Peninsula on the south coast of Coburg Island, and particularly those that breed on Princess Charlotte Monument.

Methods and Study Area

Terrain and habitat

Coburg Island is located at the east end of Jones Sound, 25 km southeast of Ellesmere Island (Figure 1). The island is approximately 3450 ha in area. It consists of extensive ice fields and mountain nunataks up to 900 m in elevation, gravel beaches, sparse vegetation, and coastal cliffs up to 300 m in

height. Princess Charlotte Monument is a spectacular, small island (< 5 ha), located about 2 km east of the Marina Peninsula on the southeastern tip of Coburg Island (hereafter referred to as the Monument, Figure 2). A series of six sea-stacks leads from the mainland to the Monument which comprises two distinct summits: a 70 m summit on the west end and the main summit tower (100 m, Figure 3). East of the precipitous summit tower, the island drops to the ocean in a series of rocky ridges and cliffs, interspersed with grassy slopes (Figure 4). During July and August in 1998, the south coast of Coburg Island including Princess Charlotte Monument was routinely surrounded with pack ice.

Bird Census

We were present on Coburg Island from 11 July to 22 August 1998. We studied breeding ecology of Thick-billed Murres, Black-legged Kittiwakes, and Glaucous Gulls, *Larus hyperboreus*, at the main colony north of Cambridge Point (Figure 2). We also visited the Monument three times in 1998 (20 July, 21 July, and 21 August; 4-8 hours per visit). We accessed the Monument by inflatable boat from our base camp on Cambridge Point, 15 km to the northwest (Figure 2). During visits and travel to neighbouring areas, all avifauna were identified and counted directly; either from a boat as we circled the Monument, or on foot. We also documented the activity of birds and, if possible, breeding status. Fish observed in chick-meals were identified on the basis of body shape and fin morphology with the aid of a spotting scope at a range of 8-10 m. The Monument itself was photographed using medium



FIGURE 1. Map showing Coburg Island, the Northwater Polynya (shaded region between Coburg Island and Greenland), and the range of breeding Atlantic Puffin colonies for both *F. a. arctica* and *F. a. naumanni*.

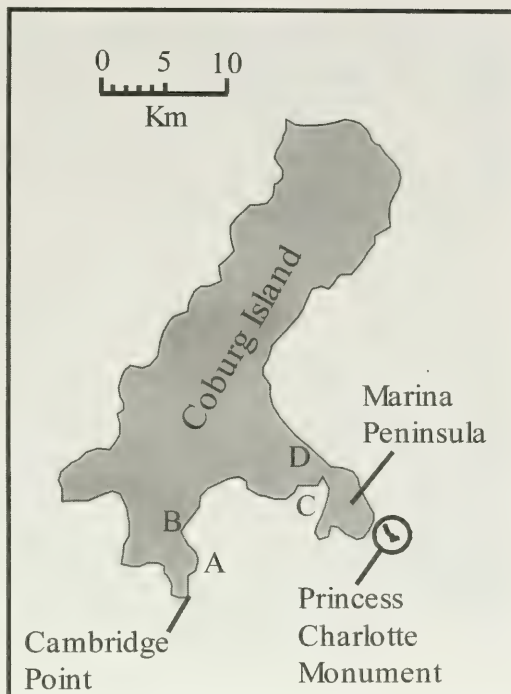


FIGURE 2. Area map of Coburg Island. Annotated locations refer to, (A) main colony; (B) Camp Beach, (C) Epic Bay; and (D) Cabin Beach.

format black-and-white film, which is now archived at the Canadian Wildlife Service, Yellowknife, Northwest Territories, Canada. We report only on bird species observed from land or while boating near shore.

We observed 17 bird species on Coburg Island in 1998; at least seven of which nested on Coburg Island (Table 1). Three of these species nested solely on Princess Charlotte Monument or on the cliff of the Marina Peninsula 100 m from the Monument (Northern Fulmar, Atlantic Puffin, Common Eider; Table 1).

Northern Fulmar *Fulmarus glacialis*

This species was commonly observed flying in the vicinity of the main colony. However, nest sites were only found on the Monument ($n = 323$ pairs) and adjacent cliffs of the Marina Peninsula ($n = 30$ pairs). Most nested high on the cliffs (range: 30–200 m in elevation), but ca. 100 pairs nested on steep vegetated slopes at the base of the Monument's main tower. Nest sites were occupied through July and August.

Mallard *Anas platyrhynchos*

One adult male was observed. Although at the extreme northern range limit for Canadian Mallards,

Mallards nest on the southwest coast of Greenland 500–800 km to the southeast of Coburg Island (Boertmann 1994).

Common Eider *Somateria mollissima*

Seen regularly in flocks (25–100 individuals) throughout July and August. Males consistently outnumbered females about 15:1 throughout the summer. Common Eiders were regularly seen close to glacial run-off creeks in Epic Bay. Four nests were found at the base of the Monument in 1988.

King Eider *Somateria spectabilis*

One flock of 15 males was observed on 14 July. Additionally, males were routinely seen on ice floes or on the sea, particularly in the area of glacial outflows in Epic Bay.

Oldsquaw *Clangula hyemalis*

We observed three groups of oldsquaw (2–4 birds each) loitering on coastal freshwater ponds near our base camp.

Glaucous Gull *Larus hyperboreus*

A common breeder at the main colony, nesting on most available promontories throughout the area (60–80 pairs). They also occurred at Princess Charlotte Monument, with 15 pairs observed on and around the two main towers. A total of 17 pairs with chicks

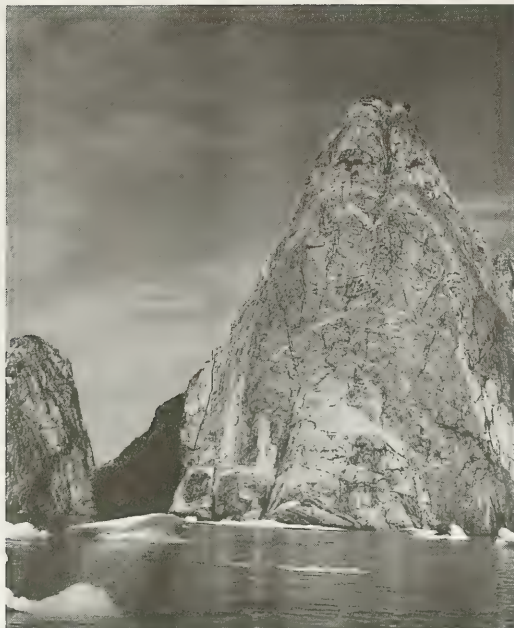


FIGURE 3. Princess Charlotte Monument, showing the main tower.

were also observed on all but one of the sea stacks leading to the Monument.

Black-legged Kittiwake *Rissa tridactyla*

This colonial seabird nested in large numbers at the main colony (30 000 pairs; Birkhead and Nettleship 1981), often interspersed with Thick-billed Murres. In addition, we found 198 active nests on the vertical cliffs of the Monument. We defined active nests as having at least one adult present, and in most cases these nests also contained eggs or chicks. Breeding phenology at the Monument was similar to the main colony in 1998, with chicks close to fledging by 21 August based upon feather development. Some flocks of adult kittiwakes (> 1000 birds) fed on amphipods (Amphipoda) near shore at the outflow areas of glacier creeks in Epic Bay. Kittiwakes also made extensive use of coastal freshwater ponds in which they bathed.

Ivory Gull *Pagophila eburnea*

Two Ivory Gulls were observed at Cabin Beach. This species appears to be a rare summer visitor in spite of the fact that one of Canada's two major breeding concentrations exists on the nearby nunataks of Ellesmere Island, 150 km to the northeast (Thomas and MacDonald 1987).

Sabine's Gull *Xema sabini*

A single individual was observed on the sea north of the main colony on 11 July 1998.

Atlantic Puffin *Fratercula arctica*

During visits to the Monument on 20 and 21 July, seven pairs of puffins were observed at the entrances to rock crevices at the base of the main tower (i.e., 14 birds). In two crevices, we found puffin egg fragments (at least 1 year old), indicating previous nesting attempts. On 21 August, fourteen pairs of puffins were observed on the same slopes that we visited previously in July. Seven of these pairs were standing at crevice entrances that we had found previously, and a further seven pairs stood at the entrances to seven other crevices (i.e., 28 puffins observed). We suggest that this is a minimum estimate assuming that some adults may have remained underground during our visits or were foraging at sea.

Puffins nested in deep and convoluted rock crevices and fissures, rather than among boulders. Little or no soil existed within these crevices. We could only view one nest chamber due to the convoluted nature and depth of crevices. The nest chamber contained dry grass, several feathers, and a puffin chick estimated to be between one and two weeks old on 21 August. This suggests a laying date of late June, assuming a 37-45 day incubation period (Harris 1984).

During 1.5 hours of continuous observations on 21 August, we observed Puffins returning with fish at five nest sites and we were able to quantify bill loads. Meals consisted of 10-15 very fresh fish, comprised almost entirely of Northern Sand Lance (*Ammodytes dubius*). Up to three juvenile Capelin (*Mallotus villosus*) were also present in some bill loads. All fish observed were 50-100 mm long.

Black Guillemot *Cephus grylle*

Black Guillemots nested in crevices at the northern tip of the main seabird colony (ca. 30 pairs) and on the west side of Cambridge Point (ca. 20 pairs). A further 100-125 pairs nested on the Monument, most at the eastern end in steep boulder-strewn slopes. Several solitary nests and small groups (< 5 pairs) were also observed on the main tower and neighboring sea stacks. The nesting colony on the Monument permitted close observation of fish species carried to chicks. We observed 30 feeds which consisted of the following: 24 sculpins (Cottidae), 2 Greenland Shrimps (*Pandalus borealis*), 2 gunnels (Pholidae), 1 Capelin (*Mallotus villosus*), and 1 Arctic Cod (*Boreogadus saida*). Most fish were 100-200 mm long.

Thick-Billed Murre *Uria lomvia*

The estimated 160 000 breeding pairs nesting at the main colony dominate the avifauna of Coburg Island (Nettleship and Evans 1985). We also found that the Monument also supports another 350-380 breeding pairs on the southern cliff-face of the main tower. Breeding was confirmed at the Monument in August when chicks were observed on ledges with adults. Based upon size of murre chicks on 21 August, phenology at the Monument was similar to the main colony. Peak of hatch occurred on 3 July.



FIGURE 4. Princess Charlotte Monument, showing steep slopes at the base of the main tower where Northern Fulmars and Atlantic Puffins nested.

Common Ringed Plover *Charadrius hiaticula*

One individual was observed at Main Camp on the edge of a freshwater pond. This species appears to be an uncommon fall transient.

Ruddy Turnstone *Arenaria interpres*

Turnstones were observed regularly in July and August at Camp Beach, north to the Marina Peninsula ($n = 32$). All appeared to be young of the year. No adult-plumaged turnstones were observed in 1998.

Parasitic Jaeger *Stercorarius parasiticus*

A pair of birds were seen on the glacial flats west of the Marina Peninsula pass on 15 July in 1998 and a second pair was observed on a visit to Cabin Beach in 1997. In both cases, no nests were found, but their behaviour suggested that both pairs were nesting.

Gyr Falcon *Falco rusticolus*

A single white-phase bird was observed at the Monument on 20 July 1998.

Common Raven *Corvus corax*

Ravens were routinely observed around Camp Beach during the course of the study. Single ravens hunted at the main colony and around the Monument. In mid-August, we observed two juveniles (presumably young-of-the-year) which accompanied a pair of adult ravens, suggesting that ravens breed on Coburg Island.

Snow Bunting *Plectrophenax nivalis*

One breeding pair and three juveniles were observed daily at Camp Beach during July and August.

Discussion

In 1998, we confirmed the existence of the most northern colony of Atlantic Puffins in Canada, located at Princess Charlotte Monument. Their presence as breeders had been previously suggested, based on the observation of one puffin carrying fish (Nettle-ship and Evans 1985), and by occasional sightings of lone individuals flying in the area and standing on grassy slopes on the Monument (A. Gaston and J. Chardine, personal communication.)

Although we did not capture or measure any of the puffins nesting on the Monument, they may be *Fratercula arctica naumanni*. This is an arctic race characterized by large body size which occurs along the north west coast of Greenland (Gaston and Jones 1998). Coburg Island is located at the northwestern margin of the range for *F. a. naumanni* nesting in west Greenland. Indeed, the nearest Greenland colony is only 250 km to the east at Saunder's Island (< 10 pairs; Harris 1984; Boertmann et al. 1996). In contrast, the closest puffin *F. a. arctica* colonies in Canada occur on Hantzsch and Dome Islands, over 1500 km to the south (Gaston and Malone 1980; Gaston et al. 1985).

TABLE 1. Summary of bird species observed on and around Princess Charlotte Monument, Coburg Island, Nunavut, in 1998, in relation to number and breeding status.

Common name	Scientific name	Location	Number	Status ¹	Breeding
Northern Fulmar	<i>Fulmarus glacialis</i>	Monument	353 pairs	common	Yes
Mallard	<i>Anas platyrhynchos</i>	Cliffs opposite Monument	30 pairs	common	Yes
Common Eider	<i>Somateria mollissima</i>	Nearshore	1	rare	No
King Eider	<i>Somateria mollissima</i>	Monument	4 pairs	common	Yes
Oldsquaw	<i>Somateria spectabilis</i>	Nearshore	15	occasional	No
Gyrfalcon	<i>Clangula hyemalis</i>	Camp Beach	10	occasional	No
Common Ringed Plover	<i>Falco rusticolus</i>	Monument	1	rare	No
Ruddy Turnstone	<i>Charadrius hiaticula</i>	Cabin Beach	1	rare	No
Parasitic Jaeger	<i>Arenaria interpres</i>	Camp Beach	32	common	No
Sabine's Gull	<i>Stercorarius parasiticus</i>	Pass Beach	4	occasional	Yes
Glaucous Gull	<i>Xema sabini</i>	Camp Beach	1	rare	No
	<i>Larus hyperboreus</i>	Main Colony*	60-100 pairs	common	Yes
Black-legged Kittiwake	<i>Rissa tridactyla</i>	Monument	32 pairs	common	Yes
		Main Colony*	30 000 pairs	common	Yes
Thick-billed Murre	<i>Uria lomvia</i>	Monument	198 pairs	common	Yes
		Main Colony*	160 000 pairs	common	Yes
Black Guillemot	<i>Cephus grylle</i>	Monument	350 pairs	common	Yes
		Main Colony	12 pairs	common	Yes
Atlantic Puffin	<i>Fratercula arctica</i>	Monument	115 pairs ²	common	Yes
Common Raven	<i>Corvus corax</i>	Monument	14 pairs	common	Yes
Snow Bunting	<i>Plectrophenax nivalis</i>	General	1 pair	common	Yes
		Camp Beach	1 pair + 4 juveniles	common	Yes

¹Status: Common, observed daily; Occasional, observed weekly; Rare, observed monthly²Estimated, based on birds simultaneously seen at crevice entrances and on the water.

*Estimated previously, Birkhead and Nettleship 1981.

Given that the waters around Coburg Island support approximately 160 000 breeding pairs of Thick-billed Murres, it is likely that the marine environment can support more than 14 pairs of puffins. This poses the question as to why there are so few puffins breeding at Coburg Island. The puffins breeding at Coburg Island and in northern Greenland nest in rock crevices on small islands. In contrast, puffins breeding at much larger colonies in temperate regions usually nest in earth burrows (e.g., south Greenland and Newfoundland; Harris 1984; Gaston and Jones 1998). Puffins breeding in the high arctic typically cannot dig burrows due to lack of soil on rocky islands. Where soil or peat does exist (e.g., at the base of large Thick-billed Murre colonies), permafrost within soils may prevent burrow nesting (Harris 1984).

On Coburg Island, there are extensive grassy slopes at the base of the Thick-billed Murre colony and on top of a rounded headland at Cambridge Point (3.5 ha.). However, holes and depressions in grass tussocks contain ice and permafrost throughout the summer. Extensive ice in burrows would prevent development of eggs and kill chicks. We suggest that puffins on Coburg Island are restricted to nesting in rock crevices free of soil, and hypothesize that the population size of puffins nesting on Coburg Island is constrained by suitable nesting habitat rather than food availability. This is in contrast to most other colonial seabird populations (Ashmole 1963; Birkhead and Furness 1985).

Another explanation considers that puffins may be constrained by the extremely short breeding season in the high arctic. Puffins typically require 36–43 days of incubation and 38–53 days for chick-rearing (Gaston and Jones 1998). In contrast, Thick-billed Murres require 29–39 days of incubation and only 21–24 days before their chicks depart to sea (Gaston and Jones 1998). Poor survival of puffin chicks may limit the potential of this colony to expand even if chicks were highly philopatric and food and nest sites were not limiting.

The high species diversity at the Monument apparently results from an absence of Arctic Foxes, *Alopex lagopus*, and the variety of nesting habitats present (i.e., cliffs, slopes, crevices, and rock scree). Strong tidal currents around the Monument may also create good feeding conditions for both near-shore (Black Guillemots) and offshore feeding seabirds (kittiwakes, murres, puffins).

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Catastrophic Windthrow in Rondeau Provincial Park, Ontario

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Catastrophic windthrow has not been quantitatively documented within a Canadian forest. Here, we report the effects of a major windstorm on a mature Sugar Maple — American Beech — Red Oak woodland at Rondeau Provincial Park, during July, 1998. Based on point-quarter sampling, we document blowdown of greater than 50% of trees, a decline in mean diameter at breast height from 37.1 to 23.0 cm, and dramatic changes in the size class distribution. We discuss a variety of natural and anthropogenic factors that account for the severity of the storm's effects and consider potential regeneration pathways, particularly given continued intense grazing by White-tailed Deer.

Key Words: catastrophic disturbance, windthrow, deciduous forest, Rondeau Provincial Park, Ontario.

The characteristic disturbance regime in deciduous forests of eastern North America is the formation of canopy gaps (Runkle 1990, 1996). Typically, these gaps are relatively small and result from death or windthrow of one or a few trees. Catastrophic disturbances that remove the majority of the canopy are infrequent in these forests, occurring less than once per millenium, but removal of 10-30% of the canopy may occur at a particular point every few centuries (Lorimer 1977; Canham and Loucks 1984; Runkle 1990; Lorimer and Frelich 1994; Frelich and Reich 1996). Large gaps were reported by early travelers in southern Ontario, such as Joseph Pickering (1832): "I saw a spot of twenty or thirty acres of wood torn up and broken off some fifty years ago by a hurricane or whirlwind and the trees scattered in heaps on the ground. I have seen similar places in different parts of the province." Nonetheless, catastrophic windthrow has not previously been documented quantitatively in Canada (Everham and Brokaw 1996). Here, we report the effects of a windstorm on mature deciduous woodland at Rondeau Provincial Park, Ontario.

On 21 July 1998, a large evening thunderstorm complex crossed southern Ontario (Environment Canada 1998). Windgusts to 130 km/hr were reported in the Windsor area, and a wind gauge at Erieau (located just to the west of Rondeau) was broken by a 180 km/hr gust (John Price, personal communication). Many trees were downed within Rondeau Provincial Park, and some areas were almost entirely deforested of canopy trees. Local deforestation was likely the result of thunderstorm microbursts — cold winds descending at high speeds from the storm's apex that hit the ground and spread rapidly outward (Dave Patrick, personal communication; Frelich and Reich 1996).

Methods

To document the effects of the 21 July 1998 windstorm at Rondeau Provincial Park, forest stand data collected on 9 June and 3 August 1998 were compared. Sampling was conducted in a mature Sugar Maple (*Acer saccharum*) — American Beech (*Fagus grandifolia*) — Red Oak (*Quercus rubra*) mesic woodland located at the extreme western edge of the Tulip Tree Trail (81°50' W, 42°16' N). This woodland is located on a 50 m wide, north-trending sand dune ridge between two interdunal Silver Maple (*Acer saccharinum*) slough swamps, and was considered the largest mature stand in the park prior to the storm (Allen Woodliffe, personal communication). Increment cores gave minimum ages of 174 years for an 80 cm dbh (diameter at breast height) Red Oak, 163 years for a 52 cm dbh Sugar Maple and 161 years for a 65 cm dbh Tulip Tree (*Liriodendron tulipifera*).

Sampling was conducted using the point-quarter method (Krebs 1989). Twenty-five sampling points were located approximately 25 paces apart on a north-south transect along the centre of the ridge. At each sampling point, we recorded the species, diameter and distance to the nearest tree (>10 cm dbh) within each of four quadrats marked by the transect and a line perpendicular to it. Distances were measured using a Sonin Combo Pro electronic distance measurer (Sonin Inc., Scarsdale, New York). For re-sampling on 3 August 1998, all but two of the original points were relocated, and the status of trees measured on 9 June 1998 was assessed. Trees that had broken along their main bole or that had been uprooted by the storm were considered dead although some tree species, for example Basswood (*Tilia americana*), are capable of sprouting from the lower trunk and eventually regenerating a mature

tree. Data for dead trees was replaced with data for the next closest living tree. Leaning trees that still had relatively intact root support were considered living, so the mortality reported is a minimum. Prior to the storm, we also recorded (i) the species of the nearest sapling (2-10 cm dbh) within each quadrant, and (ii) the presence and estimated percent cover of seedlings (< 2 cm dbh) within 1m² quadrats located at each sampling point.

Results

Fifty-one percent of the 86 living trees initially sampled were blown down or broken during the storm, causing canopy cover to decline from approximately 70% to 30-40%. The mean tree diameter was reduced from 37.1 ± 2.2 (S.E.) to 23.0 ± 1.7 cm dbh, and the estimated basal area from 36.9 to 6.2 m²/ha. Trees blown down during the storm were significantly larger than those that remained standing (mean diameter of trees blown down = 46.7 ± 2.6 cm, $N = 42$; mean diameter of trees that remained standing = 27.0 ± 2.8 cm, $N = 44$; $t = 5.15$, $df = 84$, $P < 0.0001$). No mortality was detected within the 10-19 cm stem diameter class, but mortality was greater than 45% in all other classes.

Because of the small sample sizes, there was no statistically detectable difference in the likelihood of blowdown among tree species ($P > 0.10$ for all pairwise comparisons of proportion blowdown among tree species), but the effects of the storm on forest structure were profound (Figure 1, Table 1). Sugar Maple and American Beech maintained similar importance values after the storm, but Red Oak declined by about one-third, Basswood by about one-half, and Ironwood (*Ostrya virginiana*) increased about three-fold. The major changes in the forest size-class distribution (Figure 1) resulting from the storm include: (i) a decline in the proportion of very large trees (> 70 cm dbh), (ii) a reduction in representation within mid-size classes (30-70 cm dbh), and (iii) an increase in the proportion of trees in the 10-19 cm dbh class from about 25 to 60%.

The majority of saplings within this woodland were Sugar Maple, but Ironwood, Blue Beech (*Carpinus caroliniana*) and American Beech were also frequent. Seedlings were more diverse, with White Ash (*Fraxinus americana*), Red Maple (*Acer rubrum*), Tulip Tree and Sugar Maple occurring in 16-36% of the quadrats, and Ironwood, Basswood, American Beech and Blue Beech in fewer than 10% of them. However, seedling cover averaged only 0.7% within the quadrats.

Discussion

The 50% tree mortality resulting from the windstorm at Rondeau Provincial Park is consistent with that recorded during other catastrophic wind events.

The single report of mortality in a temperate hardwood stand documented breakage or uprooting of 21.4% of trees (Everham and Brokaw 1996). Among fourteen temperate mixed forests in which the effects of windstorms have been documented, tree mortality averaged 42.6% (S.E. = 8.1%, range = 0.5-89.0%) (Everham and Brokaw 1996). High mortality at Rondeau in part resulted from the intensity of the storm and the exposed position of Rondeau along the Lake Erie shoreline, but may also be attributed to a number of additional factors considered below.

Typically, large trees are more susceptible to wind damage than small trees, as shown at Rondeau, but Everham and Brokaw (1996) provide evidence that mid-size trees are the most susceptible to damage during storms. They propose that the smallest trees are sheltered from the wind and that the largest canopy trees may be "preconditioned" by prolonged exposure to withstand high winds. This hypothesis is only partially supported by data from Rondeau Provincial Park. There was no mortality within the smallest diameter class, but larger classes were equally affected by the windstorm (to the extent that our sample allows this to be determined).

The high mortality resulting from the windstorm at Rondeau Provincial Park likely results from an interaction between four main factors (Aboud and Williams 1996; Everham and Brokaw 1996). First, the water table since the 1970s has been much higher than at anytime during the previous 50 years (Aboud and Williams 1996). The rising water table has likely killed the deeper roots of mesic tree species, thus reducing their stability. The stressed state of many trees at Rondeau is attested by the prevalence of pathogenic *Armillaria* root rot and dead crown branches (Aboud and Williams 1996). Second, the deep, fine-grained sandy soils at Rondeau provide minimal stability, particularly when they are wet. Third, past disturbances have created a positive feedback mechanism that intensified the effects of this storm. For example, logging has historically been conducted throughout Rondeau with the result that woodlands surrounding the older ridge-top stand were much younger and had a lower canopy, so they provided little protection from high-speed winds. Previous windstorms (including four reported between 1976 and 1982) had opened the canopy markedly, which made it more susceptible to blowdown during this storm (Everham and Brokaw 1996). Lastly, the increment cores demonstrate that this stand was composed of old and perhaps senescent trees that were likely prone to factors such as rot and insect infestations that would weaken their ability to withstand high winds.

Future regeneration within this woodland will depend upon the size of local gaps created by the windstorm and the assortment of seedlings and saplings present within individual gaps. The result of

TABLE 1. Frequencies of tree species at Rondeau Provincial Park before (A) and after (B) the 21 July 1998 windstorm, based on point-quarter sampling. The numbers reported are the proportion of all trees sampled (greater than 10 cm dbh) that were within a given stem diameter class for each species. Data for species lumped together as "other" in the histograms are also provided. Importance values for each tree species, out of a possible 300, are the sum of relative density (proportion of all stems), relative frequency (proportion of all points) and relative dominance (proportion of total basal area).

A.	Importance Value	Stem Diameter Class (cm dbh)									
		10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109
Sugar Maple	113.6	20.2	5.6	11.2	5.6	4.5	2.2				
American Beech	49.4	3.4	4.5	2.2	4.5	2.2					
Red Oak	36.2					1.1			2.2	1.1	1.1
Basswood	29.1		1.1	1.1	3.4	1.1	1.1				
Shagbark Hickory	23.7			3.4	2.2	1.1					
"Other"											
Tulip Tree	20.1				1.1		2.2	1.1			
Ironwood	5.9	2.2									
White Oak	5.8		1.1		1.1						
White Ash	4.6					1.1					
Butternut	4.5					1.1					
White Pine	3.8			1.1							
Red Maple	3.1		1.1								
B.	Importance Value	Stem Diameter Class (cm dbh)									
		10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109
Sugar Maple	122.6	41.6	6.7	3.4	2.2		1.1				
American Beech	76.8	11.2	7.9	2.2	2.2	1.1					
Ironwood	17.9	6.7									
"Other"											
Tulip Tree	28.2				1.1		1.1	1.1			
Basswood	17.2	1.1			1.1	1.1					
Shagbark Hickory	16.6			2.2	1.1						
Red Oak	13.1								1.1		
Yellow Birch	4.0		1.1								
Red Maple	3.8		1.1								

competitive interactions within gaps will be predicated by local light levels and the growth rate and architectural flexibility of the saplings and seedlings that are present (Poulson and Platt 1989). One major question is whether early successional, intolerant tree species will be recruited or shade-tolerant species released (Everham and Brokaw 1996). Large canopy openings and exposed mineral soils from treefalls allow regeneration of shade-intolerant and mid-tolerant tree species, such as Red Oak, Yellow Birch (*Betula alleghaniensis*), Basswood, Red Maple, Tulip Tree and White Ash (Runkle 1982, 1985; Frelich and Reich 1996). The latter four species were recorded within quadrats in the woodland, and may have well-developed seed banks, so they may be recruited within larger gaps. In smaller gaps, and possibly in some of the larger gaps too, it appears that Sugar Maple release may be the dominant regeneration process, given its prevalence among seedlings, saplings and in the 10-19 cm diameter class. Also, Sugar Maple grows more quickly within gaps than American Beech, because of its

strong apical dominance (Canham 1989; Poulson and Platt 1996).

To this point, the effect of high populations of White-tailed Deer (*Odocoileus virginianus*) within Rondeau Provincial Park has not been considered. Although a cull was conducted in 1993 to decrease their numbers (Ontario Ministry of Natural Resources 1991), populations have since rebounded and the cull seems to have had little long-term effect (Aboud and Williams 1996). High deer populations have two major implications for future regeneration within the stand considered here. First, seedling densities are very low, likely because of deer overgrazing, so regeneration patterns may depend more on the seed bank and the identity of incoming propagules than gap size. Second, preferential regeneration of tree species that are avoided by White-tailed Deer, particularly Ironwood and Blue Beech, is evident within the stand, and may become even more marked during recovery from the storm. At Long Point, 120 km to the east, browsing by deer has prevented the regeneration of tree species in areas of

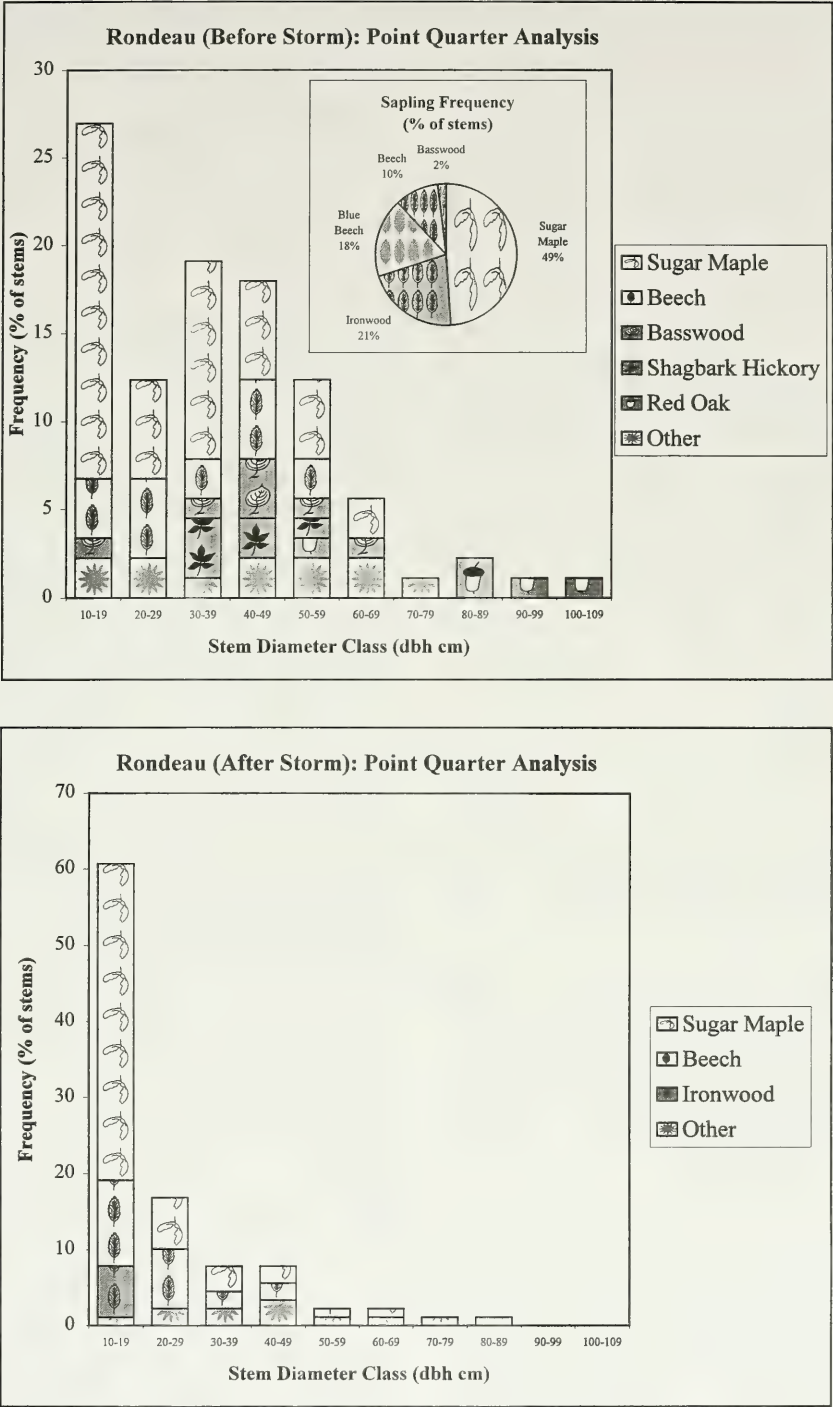


FIGURE 1. Size class distribution of trees at Rondeau Provincial Park before (top) and after (bottom) the 21 July 1998 windstorm, based on point-quarter sampling. The frequency of each species within each diameter class is presented. Sapling frequencies prior to the storm are also presented. Species comprising fewer than 5% of all stems were lumped together into an "other" category to facilitate interpretation (see Table 1 for complete data).

oak savannah, Red Oak-Sugar Maple forest and White Pine-White Cedar-Sugar Maple forest (Reznicek and Catling 1989). For these reasons, the regeneration pathway that will be followed within this woodland is by no means clear.

The most recent stated goal for Rondeau Provincial Park is "to protect and enhance the quality of the park environment, especially its unique Carolinian features, and to provide compatible recreational, educational and conservation activities" (Ontario Ministry of Natural Resources 1991). The catastrophic effects of the windstorm documented here largely resulted from a combination of past management activities and uncontrollable biological, physiographic and weather conditions. However, the regeneration patterns after this disturbance are unlikely to meet the park's goal, because deer overpopulation has inhibited the ability of Rondeau woodlands to recover structurally and compositionally after disturbances. Our results support the recommendation by Aboud and Williams (1996) that maintenance of the deer population at a much lower level is necessary to ensure appropriate regeneration of Carolinian woodland at Rondeau Provincial Park.

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Depredation of Artificial Bird Nests along Roads, Rivers, and Lakes in a Boreal Balsam Fir, *Abies balsamea*, Forest

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Predation of nests of forest birds increases near edges in agricultural landscapes and this edge effect has been extrapolated to other ecosystems, including forests managed for timber harvesting. However, current literature suggests that ecological processes occurring in fragmented forest landscapes in relation to bird nest predation differ from those occurring in agricultural landscapes, as most studies conducted in forested ecosystems have found no edge effects. Nevertheless, in both landscapes, few studies have compared predation effects along different types of edges. In a boreal Balsam Fir (*Abies balsamea*) forest, we evaluated predation risk of artificial bird nests in five forest-highway ecotones, five forest-logging road (13-m-wide) ecotones, five riparian strips along rivers, and five riparian strips along lakes. We used ground and arboreal (5-m-high) artificial nests in which we placed two Common Quail (*Coturnix coturnix*) eggs and one plasticine egg. Predation was highest in forest-highway ecotones, intermediate in riparian forest strips along lakes and forest-logging road ecotones, and lowest in riparian forest strips along rivers. The American Crow (*Corvus brachyrhynchos*), a generalist species, was an important predator along highway and lake ecotones, but was nearly absent along logging road and river ecotones. The Red Squirrel (*Tamiasciurus hudsonicus*), a forest-specialist species, co-dominated along highway and lake ecotones. Our results suggest that in this ecosystem, nest predation along edges is probably not problematic, unless human activities provide food to generalist predators. More studies are required to evaluate how new food sources resulting from human activities contribute to the establishment and sustainment of populations of generalist predators in forested areas where agriculture is absent.

Key Words: American Crow, *Corvus brachyrhynchos*, Red Squirrel, *Tamiasciurus hudsonicus*, mustelids, nest predation, artificial nests, edge type, forest fragmentation, Québec.

In agricultural landscapes, fragmentation of forest habitats increases nest predation of birds nesting near edges and in small fragments of forests (see Paton 1994). Andrén (1995) listed several reasons to explain elevated predation risks along edges: higher density of prey along edges which favors predator foraging; habitat edges used as travel lanes by predators; and presence of predators living in one type of habitat but penetrating to the neighboring less-preferred habitat. Several studies have highlighted the negative effects of generalist predators of open areas (e.g. corvids, Raccoons *Procyon lotor*, skunks *Mephitis* spp.), which are adapted to human settlement, may forage along ecotones, and may penetrate small patches of forests (Wilcove 1985; Andrén 1992; Andrén 1995; Huhta et al. 1996; Danielson et al. 1997; Hannon and Cotterill 1998). Densities of such predators increase as agriculture and other human activities increase and provide them a more abundant food supply (Angelstam 1986).

In forested landscapes fragmented by forestry practices (e.g., clearcutting), most studies reported an absence of edge effects (Rudnicki and Hunter 1993; DeGraaf 1995; Hanski et al. 1996; Huhta et al. 1996; Bayne and Hobson 1997; Huhta et al. 1998). Researchers invoked several hypotheses to explain

such results: (1) clearcuts are ephemeral open areas (DeGraaf 1995; Hanski et al. 1996); (2) forest-clearcut edges are more abrupt, making them less attractive for nesting birds and subsequently to predators (Rudnicki and Hunter 1993); (3) clearcuts are less productive habitats compared to agricultural fields (Angelstam 1986; Rudnicki and Hunter 1993; Huhta et al. 1996; Huhta et al. 1998); (4) abundance of generalist predators is lower in a mosaic of forests and clearcuts compared to a mosaic of forests and fields due to a lower influence of human activities (DeGraaf 1995; Hanski et al. 1996; Huhta et al. 1996; Huhta et al. 1998); (5) generalist predators are less common in forested landscapes (DeGraaf 1995). In a study conducted in a boreal mixedwood forest, Bayne and Hobson (1997) concluded that fragmentation caused by logging may result in little change in predator communities compared to agricultural landscape.

In a second-growth coniferous forest managed for timber harvesting in Québec, Darveau et al. (1997) observed that predation risk was low in riparian buffer strips along rivers and they hypothesized that this was related to the low abundance of generalist foragers such as American Crows, Raccoons (*Procyon lotor*), and Striped Skunks (*Mephitis mephitis*). Nevertheless, a concurrent study at the

landscape level (B. Drolet, unpublished data) suggested that crows have already settled along a highway within 5 km of the study plot.

Our objective was to determine if bird nest predation varies according to the type of anthropogenic edges typically found in a balsam fir forest managed for timber harvesting for less than a century (forest-highway ecotones, forest-logging road ecotones, double-edged riparian forest strips along lakes, double-edged riparian forest strips along rivers). We predicted that the ecotones most affected by human activities would suffer higher predation risk (forest-highway > forest logging road > riparian forest strips along lakes and along rivers), due to new sources of food supply for generalist nest predators.

Using artificial nests containing Common Quail (*Coturnix coturnix*) and plasticine eggs, we evaluated nest survival in the four types of ecotones. Artificial nests containing quail eggs have been widely used as a mean of studying predation pressure on passerine birds (Wilcove 1985; Rudnicki and Hunter 1993; Vander Haegan and DeGraaf 1996). However, recent studies have demonstrated that smaller predators (e.g. mice), that can destroy small passerine eggs, are unable to destroy effectively larger quail eggs (Roper 1992; Haskell 1995; DeGraaf and Maier 1997). As such, predation pressure by smaller predators has likely been underestimated in previous studies. To reduce this potential bias, we added a plasticine egg in each nest, which can be easily bitten by smaller predators (Moller 1989; Bayne et al. 1997; Darveau et al. 1997; Hannon and Cotterill 1998). Further, plasticine eggs allowed us to determine the relative importance of different species of predators by identifying beak and tooth marks in destroyed eggs.

Study Area

We conducted the study in Montmorency Forest area, in the Laurentian Mountains, 60 km north of Québec city (47° 19'N, 71° 09'W). Mean annual temperature is 0.3°C and the mean annual precipitation is 1527.1 mm, 38% of which falls as snow that covers the ground from the end of October to mid-May (Environment Canada 1993). The landscape is hilly, with elevations ranging from 600 to 1100 m. Several lakes, rivers and streams fringed with Speckled Alder (*Alnus rugosa*) are present. Second-growth mature forests are dominated by Balsam Fir (*Abies balsamea*), which is accompanied by Black Spruce (*Picea mariana*), White Birch (*Betula papyrifera*), and White Spruce (*Picea glauca*). Clearcuts are colonized by Common Raspberry (*Rubus idaeus*), Balsam Fir, White Birch, and locally by graminoids.

Possible bird nest predators in the Montmorency Forest area include mammals: Red Fox (*Vulpes vulpes*); mustelids (Short-tailed Weasel, *Mustela erminea*, and Pine Marten, *Martes americana*); Red Squirrel (*Tamiasciurus hudsonicus*); small mammals

(Deer Mouse, *Peromyscus maniculatus*; Southern Red-backed Vole, *Clethrionomys gapperi*; Meadow Vole, *Microtus pennsylvanicus*; and Woodland Jumping Mouse, *Napaeozapus insignis*) as well as birds: American Crow; Common Raven, *Corvus corax*; Gray Jay, *Perisoreus canadensis* (Darveau et al. 1997).

Methods

We distributed artificial nests along 20 linear transects that were 250-m-long each. Five replicate transects existed in each of four forest ecotones: forest-highway (38-m-wide highway including right of ways); forest-logging road (13-m-wide); double-edged riparian forest strips of 20-m-wide along lakes (one edge along lakes of 3-25 ha and the other edge along clearcuts of 9-10 years old); double-edged riparian forest strips of 20-m-wide along rivers (one edge along rivers of 5-15 m wide and the other edge along clearcuts of 7-8 years old). The latter transects were the same as those investigated from 1992 to 1995 by Darveau et al. (1997). All edges between open areas (clearcut or right-of-way of roads) and forests were sharp edges. All transects consisted in fir stands 50-70 years old that had not been affected by major natural perturbations such as windfall or insect outbreak, although riparian strips had been thinned (even harvest of 33% of the trees within strips) at the same time that adjacent stands were clearcut. Clearcut area (within a buffer zone of 200 m around sites) was of 5.4-11.7 ha for river transects and of 8.2-16.9 ha for lake transects. In the case of forest-highway and forest-logging road ecotones, we chose sites with uniform forest extending over 100 m on each side of the road. Vehicle traffic on the highway, that was built in 1947, was particularly high. Logging roads were built from 1963 to 1976 and were still maintained and used, but the vehicle traffic was extremely low. The distance between the different transects was at least 250 m (generally > 1000 m) and all were within a 8-km radius area.

In each transect, six arboreal nests (5-m-high) and five ground nests were alternated at 25-m intervals along a transect located at 10 m from the edge. Arboreal nests consisted of a chicken wire matrix filled with arboreal lichen to mimic Swainson's Thrush (*Catharus ustulatus*) nests, although they were slightly larger (outer diameter 12-14 cm). Ground nests were nest-sized hollows made by compacting mosses, lichens, or litter by hand. Two Common Quail eggs and one painted plasticine egg were put in each nest. Plasticine eggs mimicked quail eggs in size, color and pattern (beige with several brown spots). The plasticine egg was attached to the nest or to a shrub root with a small wire to prevent removal by predators. Nests were placed on 18 to 21 June 1996 and inspected 7 and 14 days later. Predation was assumed when at least one egg was pecked, broken, bitten, or removed. Predators were

identified by comparing bite marks in the plasticine with tooth and beak prints taken from mammal skulls and bird specimens. To minimize identification errors, two observers independently identified prints left by predators and corrected each other.

We used a Poisson regression to compare number of nests attacked by predators vs type of edges and height of nests (Agresti 1996). We included the variables edge type, nest height and the interaction edge type \times nest height in our model. We used order-independent deviances and we scaled the dispersion parameter with the deviance divided by its degrees of freedom because our data had some overdispersion (respectively Type 3 and dscale options in Proc Genmod, SAS Institute Inc. 1993). For our analysis, we summed up the number of nests that had been attacked per transect and nest height. We did not include egg type in the analysis because this variable and its interactions with other variables were not significant (all $P > 0.05$) in a previous analysis. Fisher's exact test of independence was used to test for associations between predator identity and edge type or nest height (Agresti 1996). When arboreal nests were found on the ground and when its plasticine eggs showed predation marks (6 nests), we assumed that predation had occurred before the nests fell on the

ground (4 nests), unless eggs showed marks of a strict ground predator (2 nests). In the latter case, we suspected that heavy winds had blown down the nests.

Results

Ninety-three of the 220 nests were attacked by predators. Predation was highest in forest-highway ecotones (mean proportion of nests attacked \pm SD was 0.68 ± 0.41 for ground nests and 0.73 ± 0.35 for arboreal nests); intermediate in riparian forests strips along lakes (0.56 ± 0.33 ground and 0.33 ± 0.42 arboreal) and in forest-logging road ecotones (0.72 ± 0.23 ground and 0.17 ± 0.12 arboreal); and lowest in riparian forest strips along rivers (0.16 ± 0.17 ground and 0.10 ± 0.15 arboreal). Mortality differed among edge types (Poisson regression; $F_{3,32} = 5.7$, $P = 0.003$, Figure 1), mostly as a result of a difference between predation risk along river and logging road ecotones compared to highway ecotones. Predation did not differ between nest heights ($F_{1,32} = 1.7$, $P = 0.2$) and no interaction among edge types and nest heights was found ($F_{3,32} = 1.7$, $P = 0.2$).

Predators marked 62 plasticine eggs, of which 50 of these eggs had identifiable bites or pecks, eight were taken despite their metallic attachment, and

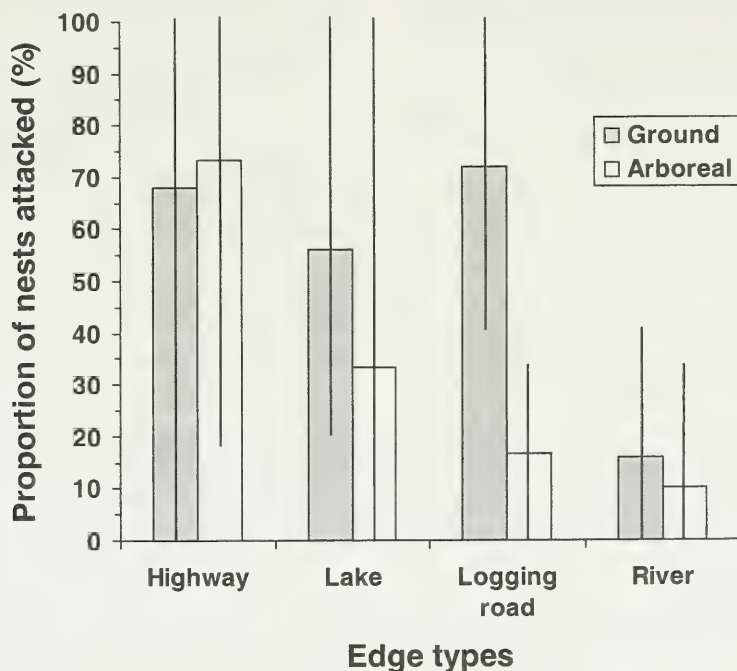


FIGURE 1. Proportion of nests attacked by predators after 14 days in four types of ecotones in a Balsam Fir forest, Québec. The bars are means (\pm extremes) of five replicates based on six arboreal nests and five ground nests each. The four types of ecotones are: forest-highway; double-edged riparian forest strip along lake; forest-logging road; and double-edged riparian forest strip along river.

four had unidentifiable marks. American Crow (16 eggs), Red Squirrel (12 eggs), mustelids (weasel or marten, 9 eggs), Snowshoe Hare (*Lepus americanus*, 5 eggs), and mice and voles (4 eggs) were responsible for 92 % of predation acts (Figure 2a). The other predators were the American Porcupine (*Erethizon dorsatum*), the Woodchuck (*Marmota monax*), the Red Fox, and the Gray Jay, one egg each.

Along highways, crows, squirrels and mustelids were the dominant predators (Figure 2a). Crows were also important predators along lakes (association between predators and treatments: Fisher's exact test, $P = 0.02$). However, crows were nearly absent along rivers and logging roads and most Snowshoe Hare identifications were made along the latter ecotone. We did not detect association between nest heights and predators (Fisher's exact test, $P = 0.2$, Figure 2b).

Discussion

Vegetation cover or complexity is often invoked to explain differences in predation rate, because dense vegetation cover (of shrubs or understory) may increase nest concealment and may affect foraging behavior of predators (Bowman and Harris 1980; Sugden and Beyersbergen 1986; Martin 1992; Sullivan and Dinsmore 1992; Seitz and Zegers 1993). As we did not sample vegetation, we cannot rule out the possibility of some differences in vegetation structure among our types of edges, particularly in the case of riparian strips, which had been thinned. However, this hypothesis cannot fully explain why predation was higher in sites located along the highway, because none of the highway sites had been thinned.

Another possible explanation for higher predation along the highway is the presence of detritus and animal carcasses along highways (M. Boulet and M. Darveau, personal observation). These new food sources may attract opportunistic predators. Plasticine eggs of nests left along the highway primarily showed predation marks done by crows, mustelids and squirrels, all known as opportunistic predators and even as scavengers in the case of the first two. Moreover, Terres (1980) reports that crows feed on traffic-killed animals.

Compared to highway edges, crows did not seem to use logging road edges as foraging sites (Yahner and Mahan 1997) and we did not observe important source of food like carcasses or wastes along these edges. Some nests along logging road edges were attacked by Snowshoe Hares and Woodchucks, but these animals have also been mentioned as artificial nest predators in other studies (DeGraaf 1995; Bayne and Hobson 1997; Darveau et al. 1997).

Predation along lakes was relatively high, but in contrast to highways, where nests attacked by crows were evenly distributed among replicates, all eight attacks by crows in forest strips along lakes were at a

single lake. Given our study design, we cannot rule out the possibility that these nests were destroyed by a single bird. However, crows were observed a few times flying over other lakes (M. Boulet, personal observation). Current literature indicate that this species is often found in the neighboring of lakes and peatlands (Godfrey 1986). As crows feed on mollusks, crustaceans and fishes (Terres 1980), it is likely possible that they also forage along lakeshores and forest-lake edges.

In comparison to lakes, few nests were attacked along river ecotones. Predation rates along rivers are within the range of values obtained by Darveau et al. (1997) from 1992 to 1995 for the same plots. Our data support their hypothesis that 20-m-wide forest strips along small-sized to medium-size rivers may be avoided by some predators in our region. Riparian edges along these narrow rivers are more abrupt than edges found along lakes and lack the natural open shore of low and peaty vegetation that often surrounds lakes. Further investigations are needed to explain why riparian strips along river are less attractive to predators than riparian strips along lakes.

As predation rate appears to be higher along highways, we believe that human activities that provide food supply may influence the presence of generalist predators and the foraging behavior in forested areas. Data from Pelletier (1995), Darveau et al. (1997), and Drolet (unpublished data), show that crows are present in our landscape. Crows are, however, less abundant in our region than in more agricultural landscapes located further south (Pelletier 1995). Due to a lack of data, we cannot assess the presence of crows before important perturbations by humans in our region; e.g., before first clearcuts in the 1930s and the construction of the highway (1947). There are however indications throughout Northeastern America that crows are now more abundant than before the colonization and that this corvid has benefited from the lumbering of forests (Godfrey 1986; John 1987; Bonney 1988; Wenger 1991; Erskine 1992; Gross 1992; Pelletier 1995). We did not find any evidence that Ravens, which also feed on eggs, attacked our nests. These birds were less abundant than crows in our study area (46 observations in 168 points for crows and 15 observations in 168 points for ravens in 1995, B. Drolet, unpublished data), but like crows, they are important scavengers and they potentially can benefit from roadkills and wastes (Godfrey 1986). To avoid increasing activity of generalist predators in forested areas, we suggest minimizing the impacts of human activities, particularly those that result in a new source of food for generalist predators (e.g., animal carcasses, detritus near roads, camps, or campings, dumps).

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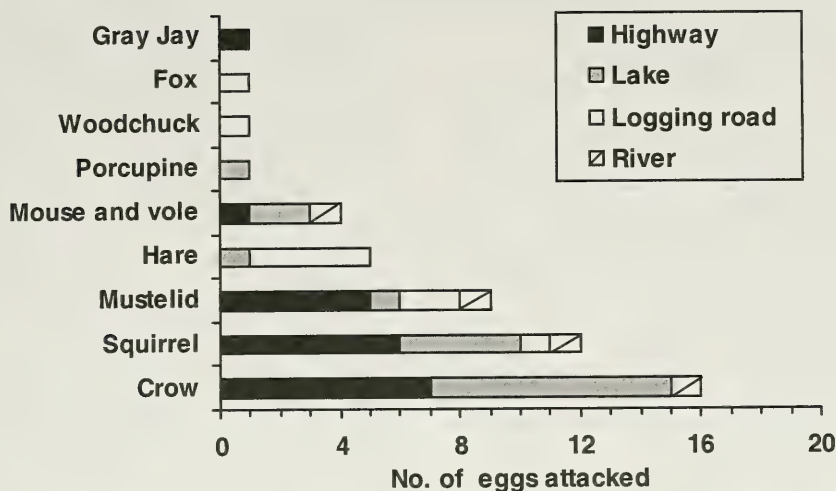
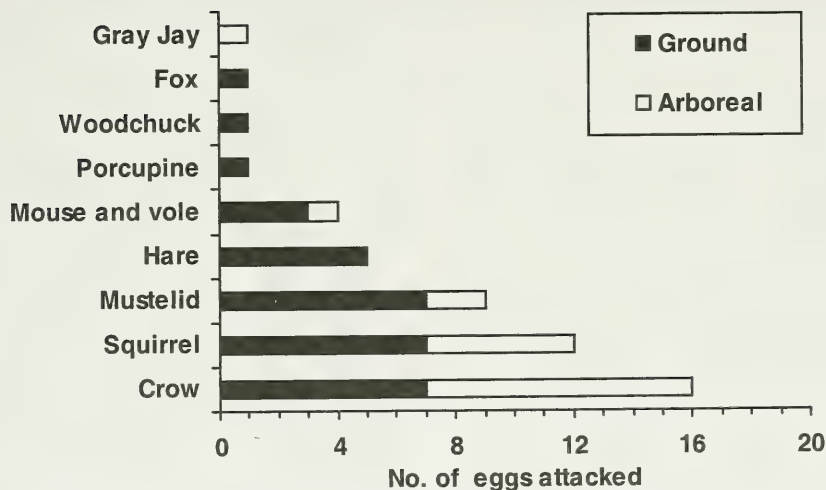
A**B**

FIGURE 2. Frequency distribution of predator species attacking plasticine eggs placed in artificial nests in a Balsam Fir forest, Québec, in relation to (a) edge type: forest-highway; double-edged riparian forest strip along lake; forest-logging road; and double-edged riparian forest strip along river, and (b) to nest height: arboreal; and ground.

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Bats of Azure Cave and the Little Rocky Mountains, Montana

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During 1996–1998, we documented eight species of bats in the Little Rocky Mountains of Phillips County, north-central Montana, USA.: Western Small-footed Myotis (*Myotis ciliolabrum*), Western Long-eared Myotis (*M. evotis*), Little Brown Myotis (*M. lucifugus*), Long-legged Myotis (*M. volans*), Big Brown Bat (*Eptesicus fuscus*), Townsend's Big-eared Bat (*Corynorhinus townsendii*), Silver-haired Bat (*Lasionycteris noctivagans*), Hoary Bat (*Lasiurus cinereus*). Presence of *Lasionycteris* was based on recorded vocalizations, all other species were captured more than once ($n = 212$ total individuals). Six species (all but the last two listed above) were captured at the mouth of Azure Cave. Sex ratios in samples of the three most common species at Azure Cave (*M. lucifugus*, *M. volans*, *E. fuscus*) were significantly biased ($P < 0.05$) for males. Five species were captured at stock ponds, and two additional species were detected but not captured at water sources. Mean hibernation counts in Azure Cave during April 1997 and 1998 were 1246 and 1120 bats, respectively; mean count during November 1998 was 1604 bats. These counts indicate more than a doubling in the number of bats using the cave since the first complete count in April 1978, and make Azure Cave the largest bat hibernaculum known in Montana and one of the largest in the Pacific Northwest and northern Rocky Mountain regions. Four bat species have been documented in Azure Cave (*M. lucifugus*, *M. volans*, *E. fuscus*, *C. townsendii*), with *Myotis* spp. consistently comprising the majority of individuals. Counts of bats in Azure Cave from previous studies during various months indicate that the cave is not used as a maternity site, probably because the cave environment is too cold (about 6.5–7.5°C throughout the year). Annual emergence probably occurs in late May to early June, fall swarming probably occurs from late August to mid-September. Weight of *E. fuscus* and *M. lucifugus* increased from summer to fall, but late-flying *E. fuscus* in October weighed less than September individuals, possibly because they had yet to attain threshold fat reserves prior to hibernation, or perhaps as a trade-off for increased mating opportunities late in the breeding season.

Key Words: Chiroptera, bats, hibernation, Little Rocky Mountains, Azure Cave, Montana.

Most knowledge of bats in Montana is based on opportunistic encounters that emphasize species distributions (e.g., Nicholson 1950; Hoffmann et al. 1969; Swenson 1970; Swenson and Bent 1977; Swenson and Shanks 1979; Shryer and Flath 1980). A study of bat rabies in western Montana by Bell et al. (1962) is a notable exception, although the specimens collected during that study formed the nucleus of new distribution records reported by Hoffmann et al. (1969). A paper on the bats of Carter County, southeastern Montana (Jones et al. 1973) is the only published ecological study, and includes discussion of habitat use, diet, and reproduction. Also noteworthy is Swenson and Shanks (1979), which made a significant contribution to our knowledge of overwintering bats on the eastern prairies. With the exception of these papers, details of distribution, phenology of occurrence, and many aspects of life-history and ecology in Montana remain poorly described for most bat species, and most data collected after 1980 remain unpublished. Despite the lack of study of bats in Montana, however, broad-scale distributions are generally well defined, and species likely to occur within the state have now been documented at least once.

In this paper we present results of bat surveys conducted during 1996–1998 in the Little Rocky

Mountains of northcentral Montana, USA. During our fieldwork, special emphasis was placed on counts of hibernating bats and timing of their occupancy in Azure Cave. Data from unpublished studies at Azure Cave are included to provide the most comprehensive description of bat activity at the cave. We also present data on species composition, relative abundance, and sex ratios of bats captured at Azure Cave, again using all available sources. We collected additional data at stock ponds and shelter caves, sites previously unstudied in the Little Rocky Mountains. These data are combined with the Azure Cave results to form a more comprehensive picture of bat activity in the Little Rocky Mountains, as well as a preliminary list of bat species occurring in this "island" mountain range. We also include analyses of seasonal changes in body weight for selected species with sufficient sample sizes. These data contribute to the scattered information on weight change from across the species ranges, and are germane to our discussion of fall activity at Azure Cave.

Study Area and Methods

The Little Rocky Mountains (47°56'N, 108°35'W) of Blaine and Phillips counties is the eastern-most mountain range formed as an island-like laccolith in the plains of northcentral Montana.

The range is approximately 20×20 km in size, rising from a base elevation of about 1128 m to a maximum elevation of about 1743 m at Antoine Butte. The northern third of the range is within the boundary of the Fort Belknap Indian Reservation, the remaining two thirds is supervised by the U.S. Bureau of Land Management (BLM) or private ownership. Much of the mountain range was burned over in 1936 (DeLap 1961), and currently supports a dominant forest cover of Ponderosa (*Pinus ponderosa*) and Lodgepole (*P. contorta*) pines, scattered pockets of Quaking Aspen (*Populus tremuloides*), and dense thickets of hawthorn (*Crateagus* sp.) and Buffaloberry (*Sherperdia argentea*) along drainage bottoms. Several stock ponds, small reservoirs, and a few permanent streams provide water for livestock and wildlife in and around the range.

The core of the Little Rocky Mountains is Tertiary igneous syenite protruding through beds of Cambrian and Devonian limestone and sandstone (Alt and Hyndmann 1986). The syenite brought with it large quantities of gold, and subsequently considerable mining activity since 1884. Numerous abandoned mine adits and a large open pit mine occupy the central portion of the present-day Little Rocky Mountains. Azure Cave (Figure 1), the largest cave in the range, is of solution origin in the steeply tilted Mission Canyon Formation of the Madison Limestone (Mississippian Period) and contains one of the largest collections of speleothems in the state (Campbell 1978). The entrance to Azure Cave, about 2 km SW of Zortman in Phillips County, is a 6-m diameter opening at 1361 m elevation leading to about 550 m of mapped passage over a vertical relief of 67 m. Azure Cave is managed by the BLM, and is protected with a bat-friendly gate a short distance within the entrance passage. Numerous smaller limestone caves, most of which extend < 30 m, are also found in the Little Rocky Mountains.

We made eight visits to the Little Rocky Mountains during our study: 3–5 June, 7–10 July, and 22–24 October 1996; 19–20 April and 7–9 October 1997; 17–18 April, 16–18 September, and 12–13 November 1998. During these trips we entered Azure Cave and conducted counts of bats on 4 June 1996, 20 April 1997, 18 April and 12 November 1998. We also netted bats at the mouth of Azure Cave during the evenings of 3 June, 7 July, and 22–23 October 1996, 7–8 October 1997, and 16–17 September 1998. Additional netting was done at the stock pond ("Pond 1") nearest to Azure Cave (about 1.5 km distance to the east) on the evenings of 8–9 July 1996.

Care was taken to minimize disturbance of bats during counts in Azure Cave. Therefore, bats encountered were not handled nor marked within the cave, and species identification in general was not possible, although it was apparent that most individ-

uals were species of *Myotis*. Remains of bats found in the cave were collected and identified later, based on skull characteristics (van Zyll de Jong 1985; Nagorsen and Brigham 1993). Counts of all bats were made independently by two observers to reduce bias in the total estimate. Route of movement through the cave during counts was similar for each observer, and cave rooms were counted simultaneously by each, one room at a time. Location of occurrence within the cave was recorded to document rooms and passages used most often by bats. Air temperature and relative humidity at various locations within Azure Cave were recorded using a thermometer and Bacharach sling psychrometer.

Bats were captured at the mouth of Azure Cave using two mist nets (50 denier: one 6 m, one 9 m) set in the same configuration each night. The exception was 3 June 1996, when two 6 m nets were used. We used up to 6 mist nets of various lengths at the pond nearest Azure Cave. Nets were set 30 min before dusk and operated for at least four hours at Azure Cave, and for two hours at the pond. Captured bats were identified, sexed, measured (weight with Pesola 30 g or 50 g scales, forearm length with a dial caliper), examined for reproductive status, and marked with colored celluloid bands (a unique combination for each night) prior to release. Because we were unsure of the reliability of our age determinations for captured bats, those data are not included in this paper. Nevertheless, the majority of bats captured in fall appeared to be adults, as were all individuals captured in spring and summer.

An ANABAT II (Titely Electronics, Ballina, Australia) ultrasonic bat detector was operated during netting sessions to indicate when bats were nearby. Bat detectors were also used during July 1996 to determine bat activity at water sources and other locations in the Little Rocky Mountains (12 sites in addition to Azure Cave). All pond sites were in unforested terrain. Detectors at these sites were set before dusk and left overnight. Calls were recorded on cassette tapes using a delay switch attached to a voice-activated tape recorder. Recorded calls were analyzed on an IBM compatible computer using an ANABAT II ZCA Interface Module and software. Identification of calls was based on call characteristics (e.g., Fenton et al. 1983; Barclay 1986) and comparison with reference recordings from captured individuals. In this paper, we consider species identifications based only on calls as tentative.

Unpublished sources of additional data on bats from the Little Rocky Mountains used for analyses in this paper include Chester et al. (1979*), Butts (1993*), and D. Sasse (Ashland District, Custer National Forest: personal communication). Where

*See Documents Cited section.

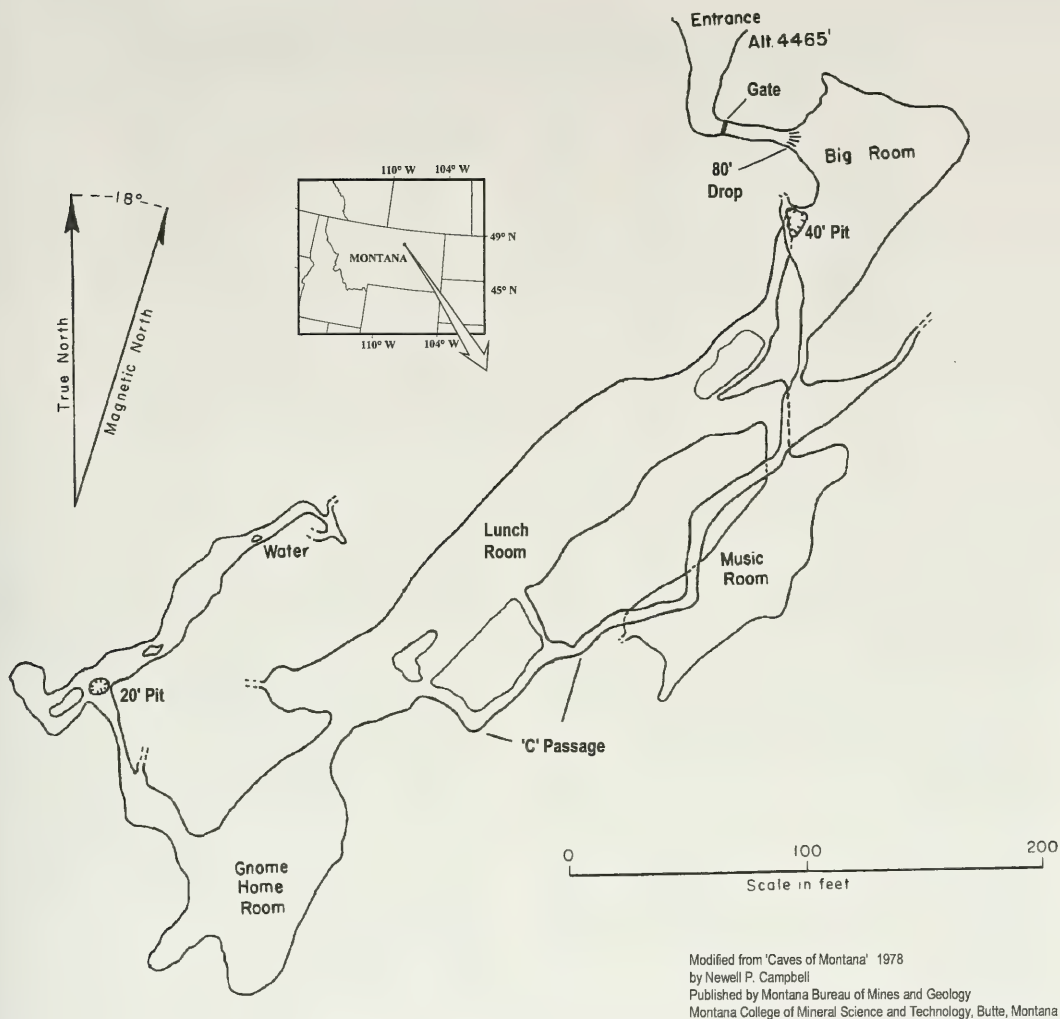


FIGURE 1. Azure Cave, in the Little Rocky Mountains of Phillips County, Montana. Modified, with permission, from Campbell (1978).

results are statistically analyzed, we follow standard procedures as described in Sokal and Rohlf (1981), with statistical significance assumed when $P < 0.05$. Analysis of variance (ANOVA) and two-sample t -test procedures were run using STATISTIX version 2.0 (Analytical Software, Tallahassee, Florida).

Results

Azure Cave (Hibernation Counts). Mean total counts for hibernating bats in Azure Cave (Table 1) during 1996–1998 ranged from 439 (4 June 1996) to 1604 (12 November 1998). Mean counts in April were 1246 and 1120 for 1997–1998, respectively. The June count was probably late enough that many individuals had already departed from the cave.

Winter counts (November through April) during our study were more than double previous counts conducted in April 1978 and March 1993 (Table 1).

Few bats were identified to species during our hibernation counts. However, more than 99% of the individuals counted were *Myotis* spp. On the 18 April 1998 count, at least three of six bats in the Big Room (Figure 1) were Big Brown Bats (*Eptesicus fuscus*). On 12 November 1998, five Townsend's Big-eared Bats (*Corynorhinus townsendii*) were identified in this room and one more was noted in the Lunch Room. Many marked bats from our September 1998 netting session were detected among hibernating clusters of *Myotis*, suggesting the majority of individuals in the cave were Little Brown Myotis (*M. lucifu-*

TABLE 1. Seasonal location of hibernating bats in Azure Cave, Little Rocky Mountains, Montana, using all available sources. Most individuals are *Myotis* spp. (see text for more details). Dashes indicate the total count includes bats from unspecified portions of the cave.

Date	Room					
	Big	Lunch	Music	Gnome Home Area	C Passage	Total
5 Mar 1993 ^a	9	250–300	no survey	4	no survey	263–313
1 Apr 1978 ^b	3	482	37	0	7	528
18 Apr 1998 ^c	6	972–1015	92–94	5–7	20–22	1101–1138
20 Apr 1997 ^c	1	1057–1167	97–131	12	7	1174–1318
4 Jun 1996 ^c	0	419–423	—	—	—	434–443
9 Jul 1978 ^b	0	0	0	0	0	0
9 Aug 1991 ^d	—	ca. 20	—	—	—	ca. 20
11 Aug 1978 ^b	—	—	—	—	—	4
30 Sep 1978 ^b	0	470	12	3	7	492
12 Nov 1998 ^c	6	1273–1529	121–153	45–52	12–17	1457–1751

^aButts (1993*).

^bChester et al. (1979*).

^cThis study (1996–1998).

^dDon Sasse personal communication, and in Butts (1993*)

gus) and possibly Long-legged *Myotis* (*M. volans*). Three skulls (Montana Natural Heritage Program collection) were recovered from the cave during our two April counts. One *M. volans* (MTHP 4075) was collected from the Lunch Room, another *M. volans* (MTHP 4062) and one *M. lucifugus* (MTHP 4063) from beyond the Gnome Home Room. Chester et al. (1979*) collected two *M. lucifugus* (one male, one female) and two *M. volans* (one male, one female) from the cave in April 1978 (Montana Fish, Wildlife & Parks collection: NG-607 to NG-610). Butts (1993*) collected three *M. lucifugus* (one male, two females), one *M. volans* (female), and one *C. townsendii* (female) from the cave in March 1993. We were unable to locate these in the University of Montana collection, where they were deposited.

Hibernating bats were most abundant (87.3–89.2% of the total count) in the Lunch Room (Table 1, Figure 1) during our winter counts, occurring in widely scattered singles and clusters of up to 30 individuals. Between 8.3–9.2% occupied the Music Room, with the remainder in the Gnome Home Room area, C Passage, and Big Room. The pattern of occupancy has been consistent during all winter hibernation counts. Few bats have been documented in the cave during July and August (Table 1).

Air temperature and relative humidity in all portions of the cave beyond the Big Room (Figure 1) ranged between 6.5–7.5°C and 85–100%, respectively, during our four counts (April 1997, 1998; June 1996; November 1998). Temperature at the top of the 80 foot drop in the Big Room was consistently 1–3°C cooler, even in June, than the lower rooms deeper within the cave. Similar climate data were recorded by Chester et al. (1979*) during August 1978. Thus, Azure Cave remains relatively cold throughout the year.

Azure Cave (Mist-netting Results). We captured 198 individual bats at the mouth of Azure Cave during our five trapping sessions: 3 June 1996 (17 bats), 7 July 1996 (2 bats), 22–23 October 1996 (17 bats), 7–8 October 1997 (15 bats), 16–17 September 1998 (150 bats). Session totals above include three individuals captured in multiple years (see below). Previously, Sasse (in Butts 1993*, personal communication) captured about 20 bats on 8 August 1991, and Butts (1993*) captured 11 bats on 28–29 September 1992. Pattern of bat activity at the mouth of Azure Cave, based on all trapping results, was bimodal (Figure 2), with peaks in spring and late summer to mid-autumn.

We captured six species of bats at the mouth of Azure Cave (Table 2). Two species comprised 87.4% of the total: *Myotis lucifugus* (98 individuals), *Eptesicus fuscus* (75 individuals). *M. lucifugus* were captured in June (15), September (82), and October (1). *E. fuscus* were captured in July (1), September (48), and October (26). Totals given above reflect only the initial capture. Three male *E. fuscus* (at least two individuals) captured and marked in October 1996 were recaptured in succeeding years: 2 in October 1997, 1 in September 1998. Smaller numbers of Western Small-footed *Myotis*, *M. ciliolabrum* (June [1], September [3], October [1]), Western Long-eared *Myotis*, *M. evotis* (September [4]), *M. volans* (September [10], October [1]), unidentified *Myotis* (June [1]), and *Corynorhinus townsendii* (July [1], September [2], October [1]) were also captured.

For all bats captured during our study, 81.9% were males. Males also comprised the majority (62.5–100%) of individuals captured during each night. For our Azure Cave samples pooled by month, males comprised 76.5% ($n = 17$) of the total for June, 100% ($n = 2$) for July, 82.7% ($n = 150$) for

TABLE 2. Sex ratios of bats captured at Azure Cave, Little Rocky Mountains, Montana, during 1996–1998 (unless indicated otherwise). Statistical analyses test for a significant deviation from a 1:1 ratio, for species where $n > 10$.

Species	Total	Males	Females	G ^a
<i>Myotis ciliolabrum</i>	5	1	4	—
<i>Myotis evotis</i>	5 ^b	2	3	—
<i>Myotis lucifugus</i>	107 ^c	93	14	65.197**
<i>Myotis volans</i>	14 ^d	11	3	4.692*
<i>Myotis species</i>	1	1	0	—
<i>Eptesicus fuscus</i>	80 ^e	65	15	33.780**
<i>Corynorhinus townsendii</i>	6 ^f	2	4	—

^aG-test for goodness-of-fit, William's correction: * $P < 0.05$, ** $P < 0.001$.

^bincludes 1 male from Butts (1993*).

^cincludes 1 male, 1 female from Chester et al. (1979*); 5 males, 2 females from Butts (1993*).

^dincludes 1 male, 1 female from Chester et al. (1979*); 1 female from Butts (1993*).

^eincludes 5 males from Butts (1993*).

^fincludes 2 females from Butts (1993*).

September, and 81.3% ($n = 32$) for October. Males of the three most abundant species (*M. lucifugus*, *M. volans*, *E. fuscus*) were captured in significantly greater numbers than females, using data from all sources (Table 2).

Ponds and Shelter Caves. We netted the pond nearest to Azure Cave ("Pond 1") for two hours each after sunset on 8 and 9 July 1996, and captured 14 bats of five species: *Myotis ciliolabrum* (1), *M. evotis* (1), *M. lucifugus* (1), *Eptesicus fuscus* (7), Hoary Bat (*Lasiurus cinereus*; 4). Most (85.7%) were males, but two *L. cinereus* were lactating females. At "Pond 1" on 9 July, *Corynorhinus townsendii* and Silver-haired Bat (*Lasionycteris noctivagans*) were identified with bat detectors but not captured. During the nights of 7–9 July 1996, *L. noctivagans* was identified with detectors at four forested sites within 2 km of Azure Cave, including one shelter cave (Two Hands Cave), but at no additional ponds. *L. cinereus* was identified with detectors at five additional ponds, but not at any sites away from water ($n = 7$). For locations other than Azure Cave and "Pond 1", *E. fuscus* was identified at nine sites (4 ponds; 5 forested), *C. townsendii* at three sites (1 pond; 2 forested), and unidentified *Myotis* at 11 sites (5 ponds; 6 forested). The only bat record for the Little Rocky Mountains prior to 1978 was an unsexed *E. fuscus* collected on 30 July 1910 (U.S. National Museum: USNM 169668) from unspecified habitat at Zortman.

Three shelter caves in the Azure Cave-Zortman area were examined during the day for roosting bats or evidence of bat use. Two Hands Cave extends a maximum of 21 m from the mouth, Smoke Hole Cave 17 m, and Grouse Gulch Cave 16 m. Scattered guano was found in Two Hands Cave (9 July 1996, 8 October 1997, 17 September 1998) and Smoke Hole Cave (17 September 1998), but there were no areas of accumulation in either. We found no evidence of bat use in Grouse Gulch Cave (8 October 1997).

Weight Dynamics. Weights of *Myotis lucifugus* in our samples increased significantly ($t = 17.58$, $P < 0.001$) between June (6.8 ± 0.4 g, $n = 14$) and September (9.7 ± 1.1 g, $n = 82$). Sexes were pooled for each period because differences were not statistically significant. June males weighed 6.6 ± 0.4 g ($n = 11$) and June females weighed 7.2 ± 0.5 g ($n = 3$). September mean weight for both sexes was 9.7 g ($n = 75$ males, 7 females). Mean forearm length also did not differ ($t = 0.72$, $P = 0.473$) between males (37.2 ± 0.9 mm) and females (37.4 ± 0.6 mm). Butts (1993*) reported mean weights of 6.0 g ($n = 3$) for hibernating individuals from Azure Cave in March, and 8.7 g ($n = 4$) for individuals netted at the cave in late September.

Weights of male *Eptesicus fuscus* varied significantly (one-way ANOVA: $F_{2,66} = 34.26$, $P < 0.001$) among monthly samples (Table 3). July males weighed 5.5 g less than males from September. October males also weighed less than September males, by 2.4 g, even though they were larger in forearm length ($F_{2,66} = 3.63$, $P = 0.031$). Differences in weights between monthly samples were significant (Bonferroni tests, $P < 0.05$) for each comparison. Butts (1993*) reported mean weight of 20.8 g and forearm length of 45.5 mm for five September males at Azure Cave, which are comparable to values we obtained for that month. Weight of September female *E. fuscus* averaged 11% more than October females (Table 3), but the difference was not statistically significant ($t = 1.81$, $P = 0.093$), perhaps because of small monthly samples. There could, however, be biological significance associated with this weight difference (see Discussion). Female forearm length was nearly identical for the two monthly samples. Females were heavier than males in both months (Table 3), and had significantly longer forearms in the September sample.

We have too few data for meaningful analyses of weight dynamics in *Myotis volans*. Nevertheless, the

TABLE 3. Weight (g) and forearm length (mm) of male and female *Eptesicus fuscus* from the Little Rocky Mountains, Montana, 1996–1998. Numbers are means \pm SD, with sample sizes in parentheses.

		Males	Females	<i>t</i> ^a
July	Weight	16.2 \pm 1.2 (6)	—	—
	Forearm	45.3 \pm 0.9 (6)	—	—
September	Weight	21.7 \pm 2.0 (38)	24.2 \pm 2.5 (11)	3.39*
	Forearm	45.1 \pm 1.4 (37)	46.9 \pm 1.5 (11)	4.24**
October	Weight	19.3 \pm 1.2 (24)	21.8 \pm 1.7 (4)	3.60*
	Forearm	46.2 \pm 1.6 (24)	47.0 \pm 1.4 (4)	0.94

^aTwo-sample *t*-test: * $P < 0.01$, ** $P < 0.001$.

single male we captured in October weighed 8.9 g and had a forearm length of 38.6 mm, 8% less than mean weight of nine September males (9.7 ± 0.5 ; range = 9.0–10.5 g) but equal in forearm length (38.6 ± 0.8 ; range = 37.5–39.7 mm). This is consistent with the pattern seen in *E. fuscus*.

Discussion

Our survey data at Azure Cave (Table 1) indicate that the over-wintering bat population has more than doubled since the first complete cave count in April 1978 (Chester et al. 1979*). Reasons for this dramatic increase are not known. The frequency and timing of disturbance by cave visitors in the past could have caused many bats to abandon the cave, but there are few records available of cave visitation. Currently, authorized entry into the cave is only by special permission. The cave has been gated since the early 1960s, but determined individuals were able to bypass the original gating system. Only in the last 5–10 years has cave security received closer scrutiny, although unauthorized entry still occurs (as recently as summer 1998). It is unlikely our counting method resulted in gross overestimates of the hibernating bat population, although there is an unknown margin of error in our counts. Our winter counts were consistently > 1100 individuals by two independent observers for three consecutive years (assuming the November 1998 count was representative for winter 1998–1999), and provide confidence that the population increase we documented is real.

The number of hibernating bats in Azure Cave make it the largest bat hibernaculum known for Montana, and one of the largest in this region of North America. Mystery Cave in the Pryor Mountains, Carbon County, Montana, supports an over-wintering population of about 500 bats, mostly *Myotis* spp. (Madson and Hanson 1992*), and is the second largest hibernaculum known for Montana. Jewel Cave in the Black Hills of South Dakota, U.S.A., has been occupied by 1100–1400 hibernating individuals in recent years (Choate and Anderson 1997). Cadomin Cave and Wapiabi (Chungo) Cave, both in Alberta, contain hibernating populations of 500–1000 bats (Schowalter et al. 1979; Schowalter

1980). There are no reported hibernacula > 100 bats in Oregon and Washington (Perkins et al. 1990), Wyoming (Priday and Luce 1997*), or British Columbia (Nagorsen et al. 1993). Hibernating bats numbered < 200 in lava-tube caves of Idaho examined by Genter (1986).

Mist-net sampling at the mouth of Azure Cave indicates a bimodal pattern of peak activity during the year, in spring and fall (Figure 2). There is relatively little activity at the cave mouth during summer or late fall. Weather conditions during each of our netting sessions were seasonal and favorable for trapping (i.e., no or only light precipitation, generally calm) and are not considered a confounding factor in the patterns we observed. Netting results are consistent with counts of bats occupying Azure Cave throughout the year (Table 1), and show that the cave is used primarily as a hibernaculum. Most of the cave beyond the first drop into the Big Room (Figure 1) is too cold to be used as a maternity roost, and capture rate in July suggests that the entrance area is little used by bats as a night roost, at least during summer.

Four species of bats (*Myotis lucifugus*, *M. volans*, *Eptesicus fuscus*, *Corynorhinus townsendii*) have been documented using Azure Cave during winter, whereas six species (Table 2) have been captured at the cave mouth in September and October. Because the majority of individuals hibernating in Azure Cave are species of *Myotis*, it is likely that a few individuals of the other species we trapped at the cave in September and October (*M. ciliolabrum* and *M. evotis*) are present within the cave during winter but overlooked. *M. evotis* has been found hibernating in a mine in Richland County about 275 km to the east (Swenson and Shanks 1979), and *M. ciliolabrum* hibernating in a mine in Musselshell County about 150 km to the south (Swenson 1970). We have no data on the relative abundance of different *Myotis* species hibernating in Azure Cave, because of our concerns regarding disturbance to the bats. Our capture data at the cave mouth, however, suggest that *M. lucifugus* is the most abundant species (Table 2).

Winter occupancy in Azure Cave appears most similar to hibernacula in Alberta (Schowalter et al.

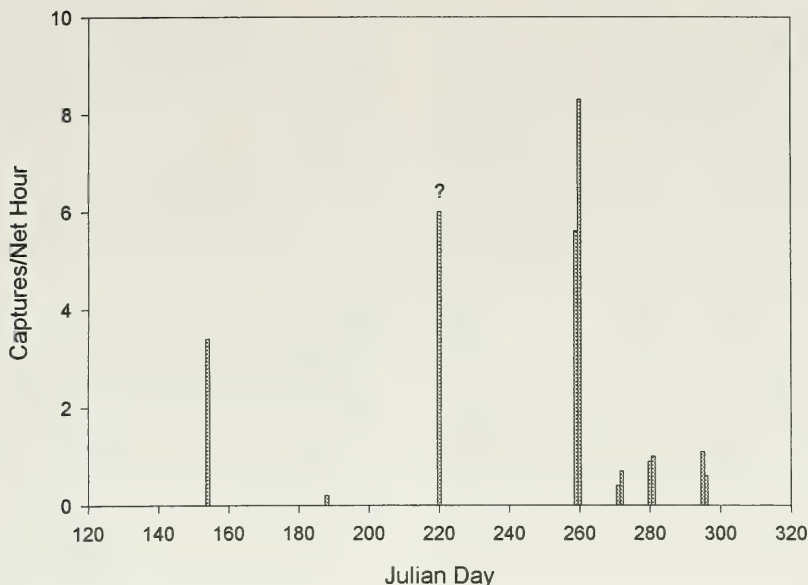


FIGURE 2. Mist-net capture rates of bats at the mouth of Azure Cave during the active season, where day 1 = 1 January. Values do not include individuals recaptured during the night of initial capture. Question mark indicates that the value for day 220 (8 August) is not verifiable. Sources of data include Butts (1993*) and D. Sasse (personal communication).

1979; Schowalter 1980), which are dominated by *M. lucifugus* and *M. volans*. Jewel Cave in South Dakota, by contrast, is primarily a hibernaculum for *C. townsendii*, which comprise 55–87% of the total count in recent years (Choate and Anderson 1997). Lesser numbers of five *Myotis* species make up the majority of the remainder, with *M. lucifugus* being the most abundant of these.

Weight dynamics of *Myotis lucifugus* and *Eptesicus fuscus* in the Little Rocky Mountains (Table 3) are consistent with other studies, in showing weight gain between early summer and fall (Schowalter et al. 1979; Fenton and Barclay 1980; Schowalter 1980; Kurta and Baker 1990). Presumably, this is because bats are accumulating fat reserves prior to entering hibernation. Female Vespertilionid bats typically are larger than males (Williams and Findley 1979). Sex-related size differences were indicated in *M. lucifugus* in our June sample, with females slightly (but not statistically) heavier, but we would expect to see stronger differences then and during fall swarming (Allen 1942; Fenton and Barclay 1980) with larger samples of females. Female *E. fuscus* were heavier and generally larger than males, also the normal pattern (Beer and Richards 1956; Kurta and Baker 1990). More interesting was our finding that male and female *E. fuscus* active in October at Azure Cave weighed less than individuals captured in September, even though

forearm measurements (an index of body size) indicated they were not physically smaller, as might be expected if they were young of the year. Schowalter (1980) indicated that a similar pattern of weight loss might occur in late-flying adult *M. lucifugus* at Alberta hibernacula, and our scant data on *M. volans* are also suggestive of the same pattern. Perhaps late-flying individuals are attempting to reach some threshold in accumulated fat reserves prior to entering winter torpor. Alternatively, bats continuing activity later than average may trade a loss in accumulated fat stores for increased opportunities of mating, which occurs during fall and early winter (van Zyll de Jong 1985; Nagorsen and Brigham 1993).

Sex ratios of bats at Azure Cave consistently favored males, except for the rarest species with < 10 captures (Table 2). This result held for all months sampled as well as for each night of netting. We also detected a male-biased sex ratio at the one pond we netted on two nights. For all bats captured during our study, 82.1% were males. Male-biased samples are the norm for the region (Schowalter et al. 1979; Schowalter 1980; Bogan et al. 1996; Choate and Anderson 1997) and farther east at similar latitude (e.g., Hitchcock 1949; Goehring 1972). Apparent biased sex ratios could be influenced by sex-related differences for roost sites in summer (Bogan et al. 1996) and unequal use of foraging habitat. Our sampling at ponds was inadequate to conclude that male

bats are more abundant throughout all habitats in the Little Rocky Mountains. Future trapping should focus on habitat use to determine if male-biased sex ratio is an artifact of uneven sampling of habitat or a result of absolute differences in the abundance of each sex. However, Azure Cave appears to be used year-round most often by male *M. lucifugus* and *E. fuscus* (and perhaps *M. volans*). Kurta and Matson (1980) showed that sex ratios favoring male *E. fuscus* could be attributed to greater male longevity. We have no data to test this observation for the Little Rocky Mountains population.

We documented eight species of bats in the Little Rocky Mountains during 1996–1998 (*Myotis ciliolabrum*, *M. evotis*, *M. lucifugus*, *M. volans*, *Eptesicus fuscus*, *Corynorhinus townsendii*, *Lasiurus cinereus*, *Lasionycteris noctivagans*). Only *L. noctivagans* was identified by calls alone. This species almost certainly is a summer resident, but its presence should be considered tentative at this time. For the species documented, only *L. cinereus* was confirmed to “breed” (two lactating females were captured in July). We assume, however, that adult bats captured at Azure Cave in September and October were engaged in reproductive behavior. Maternity roosts in the Little Rocky Mountains are unknown, although we expect some females of most species to occupy abandoned buildings or cavities in snags and stumps as documented in other locations (e.g., Vonhof and Barclay 1997; Ormsbee and McComb 1998). Female *C. townsendii* are most likely to use rock shelters or shallow caves (both are readily available in the Little Rocky Mountains) for maternity roosts (Humphrey and Kunz 1976; Dobkin et al. 1995), although use of abandoned buildings is also a possibility (see Swenson and Shanks 1979).

Of particular interest is the regular occurrence of a few *C. townsendii* throughout the year in the Little Rocky Mountains, suggesting that a small resident population is present. An autumn colony and two hibernacula of this species have been documented in Richland County 250–280 km to the east (Swenson and Shanks 1979). Our data and records in Swenson and Shanks (1979) are from the known northeastern edge of the range for this species. Most of these locations are < 150 km from the Canadian border, and indicate the potential presence of this species in Saskatchewan and Alberta, provinces from which this species apparently is not yet recorded (Kunz and Martin 1982; van Zyll de Jong 1985; Smith 1993).

Species not yet documented that may occur in the Little Rocky Mountains include Yuma Myotis (*M. yumanensis*: specimens in the University of Montana collection from Choteau County 150 km west; unpublished data), Northern Long-eared Myotis (*M. septentrionalis*: a specimen from Richland County 275 km east; Swenson and Shanks 1979), and Eastern Red Bat (*Lasiurus borealis*: a specimen in

1998 from Hill County 130 km west; K. Dubois personal communication). Of the three species, the first is most likely to be present with any regularity, while the latter two species may migrate infrequently through the area.

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Ecological History and Population Dynamics of a Disjunct Population of Brittle Prickly-pear Cactus, *Opuntia fragilis* (Cactaceae), in eastern Ontario

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A disjunct, rock outcrop, colony of Brittle Prickly-pear Cactus, *Opuntia fragilis*, in southeast Ontario was examined in 1995 to find clues to its origin, to assess its present status, and to consider the likelihood of its future persistence. The numbers, distribution, morphology and age structure of all individuals at the site were recorded and compared to a description made by others in 1967. Our initial hypothesis that this colony is relict is rejected. The colony is most likely to have resulted by human introduction as there is little evidence that it was accidentally dispersed as a burr by animals or people. Currently the colony consists of 396 plants and made up of 1683 cladodes. The population age structure shows that its numbers have been increasing steadily since 1985 when it was ravaged by cactus collectors and may have been reduced to as few as six plants. The colony is self-maintained by dispersal and establishment of separated cladodes over the rock outcrop habitat; a mechanism which may result in the establishment of new colonies elsewhere in the vicinity of Mellon Lake. The site is now protected but persistence of *O. fragilis* may depend on the absence of vandals and the necessity of periodic forest fires to inhibit the development of a shrub and tree community.

Key Words: Brittle Prickly-pear Cactus, *Opuntia fragilis*, disjunct population, Kaladar, Ontario.

In May 1967, Roland Beschel of Queen's University, Kingston, Ontario, led a botanical field excursion for the Canadian Botanical Association to examine characteristic plant communities in the Kingston area (Beschel 1967a*). A stop near Kaladar to view a remotely disjunct colony of the Brittle Prickly-pear Cactus (*Opuntia fragilis*, Cactaceae) stimulated considerable discussion and later resulted in the publication of a note on the abundance, habitat, site description and possible origins of *O. fragilis* at this location (Beschel 1967b). No information has been published regarding this unusual population since that time. A second, tiny population of the same species has recently been described (Consaul, Darbyshire and Dugal 1998) for Nepean, Ontario; this population is almost certainly a recent introduction.

Disjunct populations of any kind of organism are interesting, because they provide information on range dynamics, dispersal characteristics, and population differentiation. In addition, isolated populations and communities are vulnerable (Given 1994). Gradual or stochastic changes in their environments may lead to extirpation with no chance of natural recolonization by propagules in the absence of

neighbouring populations. Domico (1996*) has noted a recent "alarming decline" in numbers of individuals in disjunct populations of *Opuntia fragilis* in Washington State and we have noticed a similar trend in boreal populations in Manitoba (personal observations). Prior to our study nothing was known about the recent persistence and vulnerability of the most isolated colony at Kaladar.

The objectives of the present study were to: (i) establish whether a colony of *Opuntia fragilis* still exists at Kaladar, Ontario and, if so, to describe its population size, structure and dynamics, (ii) examine the kinds of evidence that may shed light on origins of this disjunct population of *Opuntia fragilis* at Kaladar, and (iii) to evaluate the chance of *Opuntia fragilis* survival at this site by identifying trends and limiting factors of population size.

Methods

Confirmation and description of the Kaladar site.

In late May 1995, we used Beschel's description (Beschel 1967b) to locate the cactus colony on a granitic outcrop adjacent to Mellon Creek, 11.5 km south of Kaladar; 77°05'W, 44°34'N. Once found, we divided the site into 15 subsites according to topography and plant communities. The sites varied in size from about 15 m² to 100 m². Each subsite was mapped and a list made of all vascular species found in it. We searched neighbouring outcrops to a dis-

*See Documents Cited section.

tance of 1 km for additional colonies of *Opuntia fragilis* and other western grassland species.

Population structure

Morphological characteristics (numbers of stems, branches and cladodes; i.e., stem segments) were recorded for each cactus plant from every subsite. Plant ages were then calculated using the maximum number of cladodes in a continuous sequence along the main stem and branches as an indicator of age in years. It was assumed that each cladode represented an annual growth increment because cladodes usually develop annually near the apices of each stem and branch (Loik and Nobel 1993; Frego and Staniforth 1985). Two factors may result in the underestimation of age by this method. Firstly, the apex of the stem or branch may fail to produce a new cladode and secondly, single mature terminal cladodes may detach from the plant and function as dispersal units (Frego and Staniforth 1985). Detachment of a cladode can usually be recognised by the presence of a scar on the stem and because subsequent cladodes are added to the shoot tip as branches, rather than as a continuation of the stem. We calculated ages to take into account missing cladodes but even so, they are best considered to be "minimum ages" because of these assumptions. Notes were made on whether plants were rooted in the substrate or detached and lying on the surface.

Geographic relationship of the Kaladar site to the known range of the species

Figure 1 shows the degree of isolation of the Kaladar site from the main range of the species. This figure is based on examined herbarium specimens (CAN, CDA, UWPG, WIN) and literature (Beschel 1967b; Boivin 1967; Scoggan 1978; Frego 1984; Domico 1996*; Hancock 1997*, 1998*) to determine the species' range Canada, but relied entirely on literature to determine its distribution in the United States (Fernald 1950; Gleason 1962; Ugent 1962; Read 1976; Wagner 1976; Barkley 1977; Scoggan 1978; Sheviak 1979; Benson 1982).

Results

Geographic range

Opuntia fragilis is widely but locally distributed throughout much of temperate, western North America (Figure 1). Its contiguous range extends from Alberta, south to Texas (Scoggan 1978) and from British Columbia (Frego 1984) east to southwest Manitoba (Frego 1984). The range becomes fragmented towards its periphery with several distinct disjunct populations occurring outside of the main range of the species, i.e. southern Arizona (Benson 1982), northern California (Benson 1982), the Gulf Islands of Washington State (Domico 1996), British Columbia (Scoggan 1978; Frego 1984), Marquette County, Michigan (Wagner 1976), southeast Manitoba-northwest Ontario (Scoggan

1979; Frego and Staniforth 1986a) and near Kaladar, Lennox and Addington County, Ontario (Beschel 1969b). The Kaladar population is the most geographically remote of these, approximately 1000 km from the nearest part of its main range in Wisconsin (Ugent 1962; Read 1976) and Illinois (Sheviak 1979) and from the nearest disjunct population in northern Michigan (Wagner 1976).

Over its main range, most plants had been found in short or mixed grass prairie where the soil had been disturbed by erosion or animals, but peripheral and disjunct populations were more often recorded or collected from granitic outcroppings beside streams and lakes. The latter observation may reflect specific habitat requirements that are only fulfilled by rocky riparian sites outside of the main species range; i.e., a well-drained substrate, the warm temperatures provided by the heat retention properties of rock surfaces, and increased light intensity which results from light reflected from adjacent water surfaces.

Present status at Kaladar

The Kaladar site was located without difficulty using Beschel's site description. The entire colony was located within the boundaries of a single south-facing slope of a granitic outcrop (Figure 2) near Mellon Lake, Lennox and Addington County, Ontario. The rock surface was deeply fissured and consisted of more or less flat shelves and steeper rises. The average inclination was about 30° and maximum outcrop height was 10 m above the adjacent stream. The colony appeared to be well established with 396 plants made up of 1683 cladodes (Table 1). Cladodes of the current year (1995) were not fully formed and not included in the census, however, many were visible as swollen buds. Most plants were found at the higher locations on the outcrop (6 m or more above the water); i.e. subsites, 1, 5 and 6, and absent from lower slopes (i.e. < 3 m) or densely vegetated subsites; i.e., subsites 3, 4, 9–14 inclusive (Figure 2, Table 1).

The average plant consisted of a main stem of three cladodes and two side branches, each of one cladode (Table 1). Subsites 1 and 7 had plants with the highest number of cladodes relative to the number of branches, whereas subsites 2, 5, 6, and 8 had the lowest cladode:branch ratios (Table 1). Figure 3a shows that the population was dominated by small plants, with larger plants occurring in steadily decreasing numbers. Six plants were made up of 16, 19, 22, 23 (2) and 29 cladodes and were significantly larger than plants in the rest of the population (Figure 3a). They were found growing under the southern edges of shrubs (*Juniperus communis* and *Rhus typhina*) in subsites 1, 5 and 8 (Figure 2). However, plant sizes and architecture (numbers and lengths of branches) varied greatly between plants even within subsites and gave large variance to the data (Table 1).

TABLE 1. Characteristics of plants of *Opuntia fragilis* found growing at 6 subsites on a rock outcrop near Kaladar, Ontario.

Subsite number*	1	2**	5	6	7	8	All subsites
Plants/site (total)	76	3	181	86	24	26	396
Plants/site (not rooted)	16	1	21	9	1	4	52
Percent unrooted plants/site	21%	33%**	12%	10%	4%	15%	13%
Branches/plant (mean±s.d.)	1.7±1.3	1.3±1.5	2.1±1.8	1.0±1.5	1.3±1.5	2.9±1.4	2.2±1.6
Branches/plant (maximum)	7	3	12	6	5	6	12
Cladodes/site	282	14	752	356	135	144	1683
Cladodes/plant (mean±s.d.)	3.7±3.1	6.5±2.1	4.2±3.4	4.1±3.3	5.6±2.9	5.5±5.8	4.3±3.5
Cladodes/plant (maximum)	23	8	29	12	11	23	29
Cladodes:branches ratio	2.5±1.3	2.0±2.3	2.1±2.1	2.1±2.2	2.5±1.9	2.1±2.3	2.3±1.3
Cladodes/main stem:							
(mean±s.d.)	2.9±1.6	2.7±1.5	2.7±1.5	2.6±1.7	3.5±1.8	3.2±2.4	2.8±1.6
(maximum)	8	4	7	9	6	9	9

*Subsites 3,4,9,10,11,12,13,14 and 15 had no cacti and have been excluded from the table.

**Sample size inadequate for meaningful comparison with other subsites.

Similarly, their estimated ages decreased steadily with the largest proportion of plants being in the one year age class (Figure 3b). Based on stem architecture, the average age is estimated at between 4 and 5 years, and the oldest at 15 years. The six unusually large plants mentioned above, were at least 12 years old, making them the only plants that were old enough to have persisted since before 1985. Unfortunately, there is no information regarding normal lifespan of individual plants of this species, but colony diameters and numbers of cladodes per colony at some of the Manitoba sites (Frego 1984) would indicate that individuals had persisted for at least 50 years.

The percent of non-rooted, recently detached cladodes was highest (21%) at subsite 1 which had an exposed aspect. On the other hand, the highest proportion of rooted plants (96%) was found in a sheltered crevice (subsite 7) where plants were relatively large (5.6 cladodes/plant, 3.5 cladodes/main stem).

Discussion

Current distribution and origins of the Kaladar population

Opuntia fragilis has one of the widest and most northern ranges of all Cactaceae (Benson 1982) due, in part, to its tolerance and adaptability to freezing conditions (Loik and Nobel 1993). However, the periphery of its range is fragmented into a number of disjunct populations, and apart from a recent introduction near Nepean, Ontario (Consaul et al 1998), the Kaladar population may be the most easterly and by far the most remote (Figure 1). There are no known populations located within the 1000 km which separates the Kaladar population from the closest part of the main species range (Wisconsin), or its nearest disjunct neighbour in northern Michigan. Natural disjunctiveness may be explained

by either one of three contrasting phenomena. Isolated disjunct populations may become established after long-distance dispersal of propagules. Alternatively, a species range may contract and leave isolated remnant populations in favorable sites, as has been hypothesized for *O. fragilis* in southeast Manitoba (Frego and Staniforth 1986a). A third hypothesis is that a population may be purposefully or accidentally introduced by humans in recent times.

Cain et al. (1998) have shown that northward Holocene range extensions of many woodland herbs has occurred at such a rapid rate that it is only explainable by a sequence of long-distance dispersal events. This hypothesis lacks credible support to explain the occurrence of *O. fragilis* at Kaladar because none of the known vectors would be an appropriate agent for such long distance without intermediate colonies between Kaladar and the contiguous range of the species. The propagules are known to be dispersed as burrs by large ungulates (Benson 1982) and otters (Domico 1996*), and also as floating stem fragments in rivers and lakes (Frego and Staniforth 1985; Domico 1996*). The absence of intermediate colonies also diminishes the hypothesis that propagules could have been unintentionally dispersed by native travellers (Beschel 1969b) or fur traders (see Frego and Staniforth 1986a).

Evidence that would support a hypothesis proposed by Beschel (1967b) that the Kaladar site may be relict from the hypsithermal period (9000–4000 BP) when grasslands reached their maximum extent might include: association with other relict grassland species, presence of independent colonies of *O. fragilis* between the Kaladar colony and the main range of the species, a hypsithermal history of grasslands in the area which may persist to the present-day. We did not find any indisputable western, relict grassland species in association with *Opuntia fragilis* at

the Kaladar site in 1995 (Table 2); however, this argument hinges around the interpretation and definition of what constitutes a "western grassland species". Beschel (1967b) listed 13 "species of distinctly western or southern affinity" and a skink (*Eumeces fasciatus*) at Kaladar to support this hypothesis. On the other hand, Scoggan (1978) classified 12 of Beschel's 13 "western/southern" species as either eastern ("EE"; i.e. *Lechea intermedia*, *Panicum bicknellii*, *Penstemon hirsutus*, *Viola fimbriatula*, *Wolffia columbiana*, *Wolffia punctata*) or transcontinental ("X"; i.e. "*Aster ptarmicoides*", *Dracocephalum parviflorum*, *Hedeoma hispida*, *Potentilla arguta*, *Rhus radicans*, *Silene antirrhina*). The thirteenth species is *O. fragilis* which he classifies as western ("WW"). The local occurrence of the Five-lined Skink does not represent part of an ancient western grassland fauna as it too has an eastern North American distribution (see Cook 1984; Weller and Oldham 1986 for Ontario, and references in these for North America). Although a "prairie peninsula" and oak savannas once extended into southern Ontario from central North America during the mid Holocene (Transeau 1935; Schmidt 1938; Bartlein et al 1980; Szeicz and MacDonald 1991), they now persist in Ontario only as isolated remnants (Roberts et al 1977; Reznicek and Maycock 1983; Catling et al 1992; Catling and Catling 1993) and *Opuntia fragilis* is not known from these areas.

Perhaps the most plausible origin hypothesis is that the species has been introduced in recent times (e.g., in the last 100 years) by people who like to grow exotic or curiosity plants around homes or cottages in the vicinity of Mellon Lake. *Opuntia fragilis* is a species that has received a lot of attention from gardeners and other enthusiasts of unusual plants (Hancock 1997*, 1998*). The potential for "escapes" by means of water/animal dispersed cladodes is high. South-facing, granitic slopes (see Rejmanek 1971; Nobel et al. 1992) with sparse vegetation, like that at Kaladar, are suitable sites for colonisation by *O. fragilis*. There is anecdotal evidence of two additional colonies in the vicinity of the Kaladar colony (L. Consaul, P. McCoy, personal communication). These are both nearby and on the same water body as the study site and hence, are likely to be daughter or parental colonies. The occurrence of a declining population of *O. fragilis* at Nepean, near the outskirts of the City of Ottawa (Consaul et al. 1998) is believed to be introduced. Substantial botanical exploration of granite barrens in recent years have also failed to reveal new, independent colonies of *Opuntia fragilis* (Brownell et al. 1996).

Present status

Plants of *O. fragilis* are capable of growing very large (to 1 or 2 m in diameter) and consisting of hundreds of cladodes (e.g., Post Island, Big Whiteshell Lake, Manitoba; Frego and Staniforth unpublished

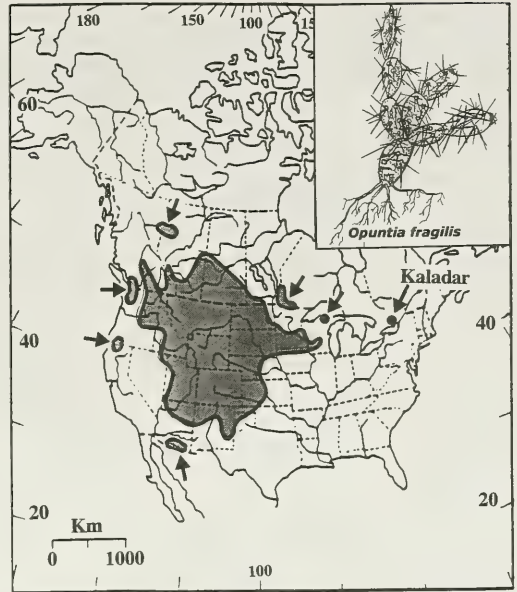
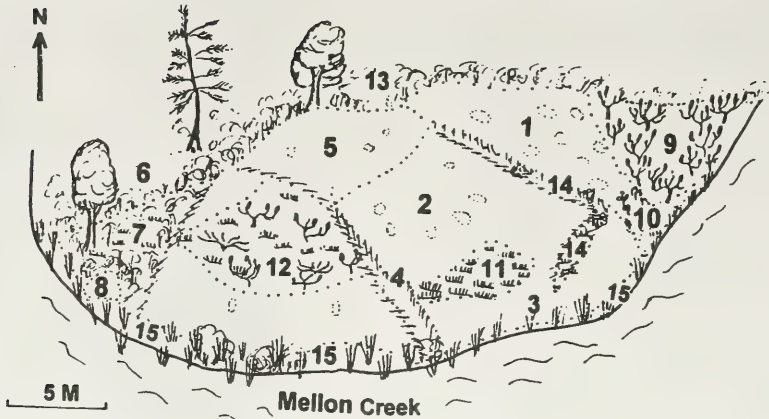


FIGURE 1. Distribution of *Opuntia fragilis* (Brittle Prickly-Pear Cactus) in North America, showing the main range (outline), disjunct populations (arrows), and remote populations (circles) in Michigan and near Kaladar, eastern Ontario.

data). However, 390 (99.5%) of the plants at Kaladar were small with less than 15 cladodes (Figure 3a). The scarcity of cohorts which pre-date 1985 was evident in our age structure data (Figure 3b,c). This date coincided with a report of a massive collection by "vandals" (Klinkenberg 1987). The population appears to have declined from about 300 individuals (Beschel 1967b) to perhaps as few as six plants (our data). Likely, overhanging shrubs had hidden the survivors from human vision and depredation for many years and yet the southern exposure had not caused detrimental shading. The population appeared to have recovered to its former level by 1995.

The percent of non-rooted plants was greatest at subsite 1 (21%), indicating that this was an area in which considerable fragmentation of stems had occurred and from which dispersal was taking place. This was an open site and most prone to physical effects of rain splash, wind and animal contact, all of which are factors causing stem fragmentation and may act as vectors in dispersing the resulting free cladodes (Frego and Staniforth 1985). This hypothesis is further supported by the observation that most rooted "parent" plants were relatively small (3.7 cladodes/plant, 2.9 cladodes/main stem) and possessed short lateral branches. This growth form is interpreted as the result of frequent fragmentation of the stems. On the other hand, the highest proportion of rooted plants (96%) was found in a sheltered



Subsites:

1. Slope to SE.

Steep slope with drainage. Moist.
Plant cover: vascular 25% (herbs),
non-vascular 60%.

2. Main slope to S.

Main sloping surface of outcrop.
Dry and highly disturbed.
Plant cover: vascular 5% (herbs),
non-vascular 60%.

3. Wedge of exposed rock 1.

Dry rock exposure between grassy subsites
Plant cover: vascular 5% (herbs),
non-vascular 20%.

4. Wedge of exposed rock 2.

Exposed rock between grassy subsites.
Plant cover: vascular 20% (herbs),
non-vascular 20%.

5. Top of rock outcrop.

Main open plateau at the highest exposure
of the rock. Highly disturbed. Small crevices
filled with leaf litter. Plants restricted to crevices.
Plant cover: vascular 15% (herbs, shrubs),
non-vascular <5%.

6. Steep slope.

Steep slope to the SW. Open area bounded
by trees and shrubs.
Plant cover: vascular 40%,
non-vascular 30%.

7. Grassy crevice.

Well vegetated wide crevice, moist, drainage,
peat accumulation.
Plant cover: vascular 80% (graminoid and shrubs),
non-vascular <10%.

8. Exposed rock.

Open rock surrounded by shrubs.
Plant cover: vascular 20% (shrubs),
non-vascular 25%.

9. Grove of sumac.

Sloping eastern edge of site.
Plant cover: vascular 65% (shrubs, herbs,
graminoids),
non-vascular 20%.

10. Patch of tree/shrub seedlings.

Low, moist area, with some soil build-up
Plant cover: vascular 60% (tree and shrub
seedlings, graminoids, herbs),
non-vascular 30%.

11. Grassy slope.

A vegetated patch within the open rock
outcrop, some soil build-up.
Plant cover: vascular 60% (graminoids, shrubs),
non-vascular 25%.

12. Shrubby area.

Shallow, wide slope, well vegetated,
some soil accumulation.
Plant cover: vascular 70% (shrubs, herbs),
non-vascular 10%.

13. Shrubby top of plateau.

Undulating, top of outcrop forming
northern boundary of the study site.
Plant cover: vascular 80% (trees, shrubs,
graminoids, herbs),
non-vascular 10%.

14. Crevice.

Narrow rock crevice, filled with peat.
Plant cover: vascular 25% (shrubs),
non-vascular 15%.

15. Riparian zone

Densely vegetated margin of Mellon Creek.
Plant cover: vascular 80% (shrubs, climbers,
herbs, graminoids, ferns, aquatics),
non-vascular 5%.

FIGURE 2. Map of the rock outcrop bearing the population of *Opuntia fragilis* near Kaladar, Ontario showing subsites discussed in the text. The maximum outcrop elevation is approximately 10 m above the stream surface, with a slope of 30° to the south.

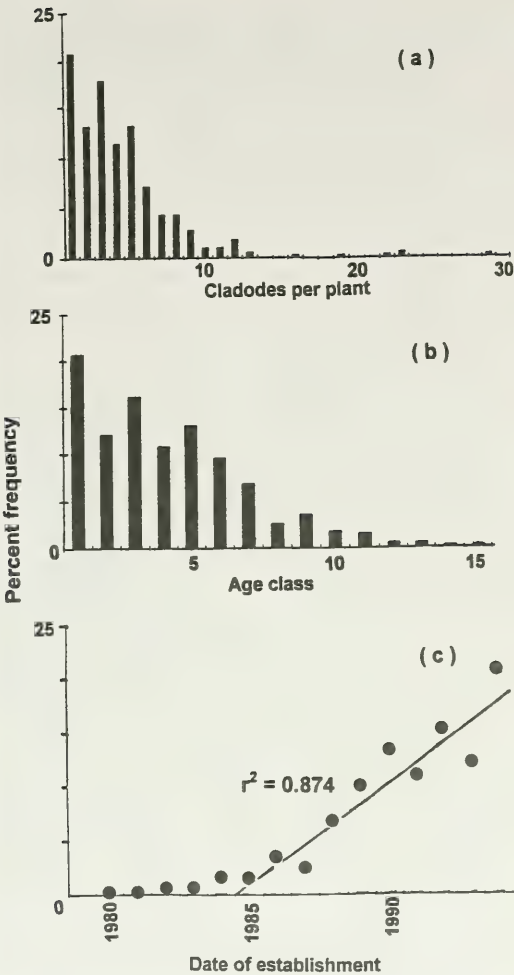


FIGURE 3. Population structure of *Opuntia fragilis* at Kaladar, Ontario. a) Size class frequencies, based on cladode numbers per plant. b) Age class frequencies. c) Estimated population recruitment since 1980, based on plants surviving until 1995.

crevice (subsite 7). Presumably free cladodes would accumulate here and root, having rolled down the slope from subsites 1, 5 and 6. These plants were larger (5.6 cladodes/plant, 3.5 cladodes/main stem) and less branched. This suggested that once established the plants were not prone to future fragmentation of stems and out-dispersal of free cladodes and would more likely grow as longer, less branched forms. Such a pattern of population dynamics has been noted in Manitoba (Frego and Staniforth 1985); i.e., the majority of cacti occupy the higher, exposed parts of rock outcrops from which cladodes are dispersed either by animals, or by rolling down-slope into crevices or the adjacent water-body. Repeated fragmentation produces clumped, low plants with

numerous short branches. However, in sheltered micro-sites, plants remain intact and grow taller and relatively unbranched but risk competition from taller species.

Future survival

Protection of relict cactus and prairie sites from development and other human related damage is critical to their survival. Until recently, “vandals and cactus fanciers” appear to have been a major factor in reducing the size of the Kaladar population of *Opuntia fragilis* (Klinkenberg 1987) and at other locations (Read 1976). Fortunately, the Kaladar site and its cactus colony have stimulated sufficient curiosity to have warranted inclusion as an International Biological Program area (see Macdonald and Hainault 1974*). The Nature Conservancy of Canada bought the property in 1987. It is now known officially as the Sheffield Conservation Area and is administered by Quinte Conservation Authority (P. McCoy, Quinte Conservation; S. Turner, Nature Conservancy of Canada, personal communication). *Opuntia fragilis* is classified as “rare” in Ontario based on the single, described site of occurrence at Kaladar and a few locations in the extreme west of the province (Argus and White 1977).

TABLE 2. Vascular plants growing on the rock outcrop with *Opuntia fragilis* at Kaladar, Ontario. Nomenclature follows Scoggan (1978). Most taxa are represented by voucher specimens located at the Herbarium of the University of Winnipeg (UWPG)

Trees	Herbs
<i>Acer rubrum</i>	<i>Agropyron repens</i>
<i>Fraxinus nigra</i>	<i>Agrostis hyemalis</i>
<i>Pinus strobus</i>	<i>Comandra umbellata</i>
<i>Quercus alba</i>	<i>Danthonia spicata</i>
<i>Quercus rubra</i>	<i>Deschampsia flexuosa</i>
<i>Ulmus americana</i>	<i>Eupatorium purpureum</i>
	<i>Hieraceum florentinum</i>
	<i>Hypericum perforatum</i>
Shrubs and vines	<i>Onoclea sensibilis</i>
<i>Amelanchier alnifolia</i>	<i>Opuntia fragilis</i>
<i>Arctostaphylos uva-ursi</i>	<i>Osmunda regalis</i>
<i>Cephalanthus occidentalis</i>	<i>Panicum lanuginosum</i>
<i>Chamaedaphnae calyculata</i>	<i>Panicum linearifolium</i>
<i>Diervilla lonicera</i>	<i>Pentstemon hirsutus</i>
<i>Ilex verticillata</i>	<i>Poa compressa</i>
<i>Juniperus communis</i>	<i>Polygonatum pubescens</i>
<i>Myrica gale</i>	<i>Potentilla arguta</i>
<i>Parthenocissus quinquefolia</i>	<i>Rumex acetosella</i>
<i>Prunus virginiana</i>	<i>Selaginella rupestris</i>
<i>Rhus aromatica</i>	
<i>Rhus radicans</i>	
<i>Rhus typhina</i>	Some plants of
<i>Rubus allegheniensis</i>	Cyperaceae and Compositae
<i>Spiraea alba</i>	were in a vegetative
<i>Vaccinium angustifolium</i>	state and defied
<i>Viburnum rafinesquianum</i>	attempts at identification.
<i>Vitis réparia</i>	

Competition from successional herbs, shrubs and trees may be a future threat to colonies of this species (Burger and Louda 1995; Frego and Staniforth 1986b; Domico 1996*) as well as other grassland relicts in Ontario (Roberts et al. 1977*; Reznicek and Maycock 1983). A forest fire had burned the site (Macdonald and Hainault 1974*) probably in the late 1950s or early 1960s, and a photograph taken in 1967 by W. Dore and R. Beschel (unpublished) showed that the outcrop vegetation was recovering but still sparse. In 1995, the presence of shrubs, young trees and leaf litter indicated that the absence of fire or even severe drought (Benson 1982) would be disadvantageous to the continued survival of *Opuntia fragilis* at this location. Fire has been recommended as a management tool for this species (Domico 1996*), and for relict prairie communities in Ontario (Roberts et al. 1977; Catling et al. 1992).

We saw no signs of disease or herbivore damage to the cactus plants, but insect damage has been significant elsewhere (Maw and Molloy 1980; Burger and Louda 1994, 1995).

Persistence of *O. fragilis* at Kaladar has depended upon continued suitability of local conditions since the time of its colonization. Even so, we noted vegetative growth only and according to Bernshaw and Bernshaw (1984) this colony has never been known to bloom. In 1995, we failed to find remnants of flowers or fruits from the previous year (1994), and there were no developing flower buds for the current year (1995). Frego and Staniforth (1985) have noted that flowering years were very infrequent in populations in southeast Manitoba (although 1980 was an exception) and the production of viable seeds has not been reported. Thus, reproduction appears to be entirely by fragmentation in Manitoba and perhaps this is also true for the population in southeast Ontario. It appears that peripheral northern disjunct populations of *O. fragilis* self maintain by fragmentation and are dependent upon persistence of open, warm sites for their continued survival. Periodic droughts may favour *Opuntia fragilis* and eliminate potential, more vigorously growing competitors (Benson 1982), but the probable absence of genetic variability in this clonal population makes it vulnerable to habitat changes.

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Road Mortality of Snapping Turtles, *Chelydra serpentina*, in Central Ontario During their Nesting Period

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In the early summer of 1993–1995, a survey was conducted in central Ontario to determine the amount of road kill of Snapping Turtles during their nesting period. Peak nesting occurred during mid June in all three years. The annual mortality of Snapping Turtles during this period was 30.5% of all observed turtles. Only 24% of the dead snapping turtles sampled were mature females. Snapping Turtle road mortality during the nesting period was high and could have negative impacts on the sustainability of local populations.

Key Words: Snapping Turtle, *Chelydra serpentina*, nesting, road mortality, Ontario.

Road mortality of terrestrial vertebrates has been a concern to wildlife managers as local extirpation or decline of species has been associated with it (Rosen and Lowe 1994; Fahrig et al. 1995). Studies have shown that animals suffer greater mortality with higher traffic volume and speed (Oxley et al. 1974) and that amphibians and reptiles are particularly vulnerable to road mortality, especially where roads are constructed through wetlands (Ashley and Robinson 1996).

The impact that road mortality has on populations of long-lived species such as the Snapping Turtle, *Chelydra serpentina*, could be especially detrimental due to their inherent life history traits. This species has a low annual recruitment (Galbraith et al. 1989), long life expectancy (Galbraith and Brooks 1987; Brooks et al. 1988, 1991) and the ability to reproduce into the late stages of their life (Brooks et al. 1988, 1991a, 1991b; Congdon and Gibbons 1990). Remaining iteroparous during a long life span increases the chances of successful reproduction despite low recruitment success (Congdon and Gibbons 1990). However, heavy adult mortality from road kills (or other anthropomorphic events such as poaching, etc.) could result in population declines (Brooks et al. 1991a). Populations adjacent to major roads are not the only ones at risk as Snapping Turtles will migrate from their home range (Kiviat 1980; Obbard and Brooks 1980; Congdon et al. 1987) and have been documented to migrate up to 13.8 km post nesting (Obbard and Brooks 1980).

Snapping Turtles are observed crossing roads or on the side of roads during the nesting season each year. Many of these turtles get killed; however, the effect of this mortality on the population is not known. It has been assumed that the majority of the turtles observed and killed are females who are attempting to oviposit. The purpose of this study was to determine the level of Snapping Turtle road kill along the

highways and roads of Haliburton County in central Ontario, the timing of nesting in this section of the species' range, and what proportion of road kills observed during that time were mature females.

Study Area

The study was conducted in the Minden Administration area of the Ontario Ministry of Natural Resources. This land base covers approximately 4555 km² in central Ontario, north of the Kawartha Lakes to the southern edge of Algonquin Park, with the centre of the study approximately 60 km southwest of the well studied Lake Sasajewun Snapping Turtle population (Galbraith et al. 1988). The study area is primarily in Haliburton County, but extends into both Peterborough and Victoria Counties to the south. It is in the Great Lakes-St. Lawrence Basin and is predominately on the Precambrian Shield, forests are comprised of tolerant and intolerant hardwoods. The southwest portion of the study area is of middle Ordovician origin, comprised of limestone and non-forested, agricultural land. The study area is transected by four main corridors, highways #35, #121, #118 and #503 (Figure 1). There are numerous secondary and tertiary roads including cottage roads and timber access roads (not detailed on Figure 1).

Methods

The survey was conducted annually over 60 days, from 15 May though 15 July in 1993, 1994 and 1995. Staff from the Minden office of the Ontario Ministry of Natural Resources were requested to document Snapping Turtles along the side of the road during their travels. The study pertained strictly to Snapping Turtles as most employees were able to identify this species. Only Snapping Turtles documented along a roadside were included in this survey. Snapping Turtles were noted as alive or dead. If



FIGURE 1. Location of Snapping Turtle observations on roads in Minden Area.

alive, the activity of the turtle was noted, whether crossing the road or nesting. Peak nesting period was assumed to occur when the greatest number of

Snapping Turtles were observed on the side of the road attempting to oviposit. If the turtle was dead, it was recorded as either a recent kill or old kill. If the

specimen was in good condition, it was collected and necropsied at the Minden Office. The date, time, number of turtles observed and location of observation was recorded. Universal Transverse Mercator (UTM) coordinates to the nearest 100 m² were assigned to each observation. Records were edited for duplicates by comparing the UTM coordinates, time and date of observations, and the recent or old kill designations.

Attributes of dead Snapping Turtles collected were sampled; sex of the turtle was determined by external secondary sexual characteristics (Mosimann and Bider 1960; White and Murphy 1973), or internal examination; age was estimated by counting the annuli on the costal scute (Galbraith and Brooks 1987; Galbraith et al. 1989). Stage of maturity was determined by internal examination by the presence of developed ovaries or testes and listed as male, female or immature.

Results

Snapping Turtles were first observed on the road or on the side of the road beginning in late May during all years of the study. The first record of nesting occurred on 10 June, 23 May and 7 June in 1993, 1994, and 1995, respectively. The peak in numbers of turtles observed on roads, presumed to correspond with peak nesting, was 12 to 18 June, 13 to 17 June, and 14 to 22 June in 1993, 1994, and 1995, respectively (Figure 2).

In the three years, 279 Snapping Turtles were documented, 30.8% ($n = 86$) of which were road kills. Only three observations of Snapping Turtles along the road were made after 30 June. There were 105 Snapping Turtles documented in 1993, 88 in 1994 and 85 in 1995. Dead turtles accounted for 35.2% ($n = 37$) of the observations in 1993; 23.9% ($n = 21$) in 1994; and 32.6% ($n = 28$) in 1995. The majority of the dead turtles ($n = 69$, 80.2%) were found along a major highway.

The four areas of highest concentrations of Snapping Turtle observations were on highway #35 north of Kilcoo Camp to the junction of highway 121 south of Minden; highway #121 northwest of Kinmount to the junction of highway #35; highway 121 west of Ingoldsby Road; and highway #35 north of Pine Spring Road to Wren Lake (Figure 1).

We examined 25 of the 86 documented road killed Snapping Turtles. Of these Snapping Turtles necropsied, 24% ($n = 6$) were mature females, 36% ($n = 9$) were immature females, 20% ($n = 5$) were mature males, 4% ($n = 1$) were immature males, and 12% ($n = 3$) were immatures whose sex could not be determined. The remaining turtle ($n = 1$) was decomposed when necropsied and therefore the sex could not be determined (Table 1).

The smallest mature female sampled had a carapace length of 264 mm. The largest immature female sampled had a carapace length of 270 mm. All

females greater than 280 mm carapace length were mature. The smallest mature male sampled was 276 mm carapace length. All males greater than this size were mature.

All of the mature females except one were collected during peak nesting. Only one mature male was collected during peak nesting, three were collected prior to nesting and the other post nesting. There were three immature Snapping Turtles collected during peak nesting, five prior to peak nesting and five post peak nesting.

Discussion

In the Minden study area, observations of Snapping Turtles on roads peaked by mid-June in each year and there were few observations after 30 June. Although this survey was oriented around the nesting period, Snapping Turtles were rarely observed along the roadside outside of the survey dates (Haxton, unpublished data). In contrast, Ashley and Robinson (1996) found that Snapping Turtle road mortality remained at a constant rate until September, then peaked. The location of their study area in southwestern Ontario in close association with a wetland (i.e., causeway) may have contributed to this pattern as turtles moved to or from the wetland outside of the nesting season. Snapping turtles in central Ontario are active from mid-May until late August (Obbard and Brooks 1981). Their level of activity/movement was greatest until the nesting period and declined as the season progressed (Brown and Brooks 1993). Therefore, the dates of the survey were considered adequate to document the majority of the migrations by Snapping Turtles in central Ontario.

Over all three years, 30.8% of the Snapping Turtles observed on roads were killed. How this applies to the population at large is difficult to quantify and therefore should not be used as an extrinsic mortality rate. This study pertained to the Snapping Turtles observed along the road and did not attempt to obtain population estimates in wetlands adjacent to the roads. It is difficult to determine the impact road mortality has on a population without absolute density estimates of that species (Bernardino and Dalrymple 1992).

Four areas of high Snapping Turtle concentrations were noted. These areas were major highways constructed through or adjacent to wetlands. They are also along the main route to the Minden office. The high occurrence of observations in these areas may be due to the suitable habitat or and artifact of highly traveled areas. Due to the number of participants in this survey, an accurate estimate on the time expended conducting Snapping Turtle observations, distance traveled or area covered could not be determined. This information would allow for more accurate interpretation of the observations and possible impacts on Snapping Turtles in specific areas.

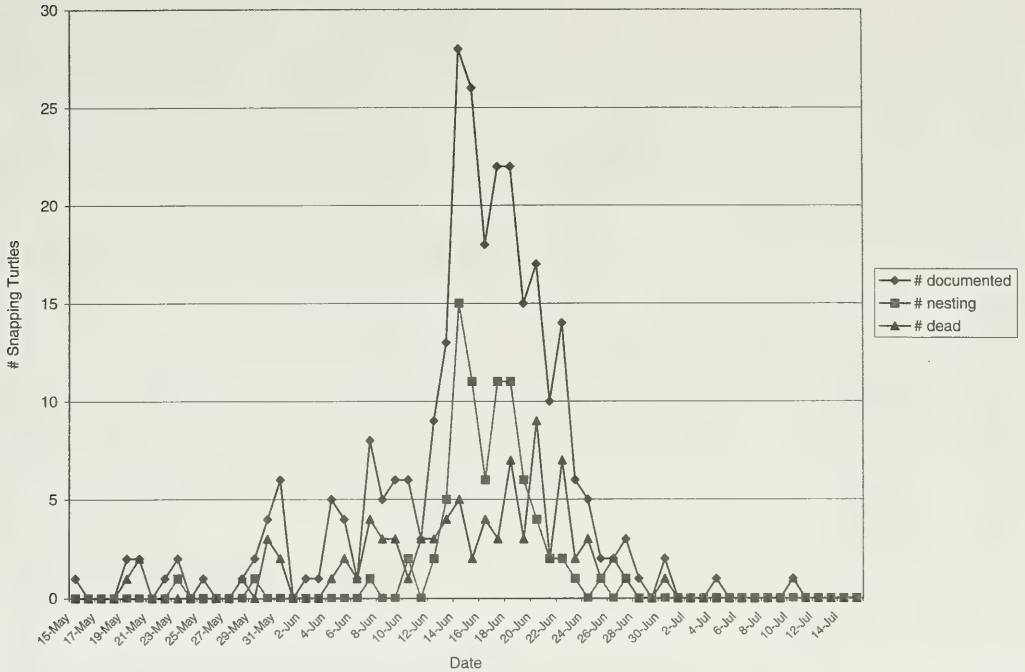


FIGURE 2. Date of Snapping Turtles documented along the road during 1993–1995.

Although only 25 of the 86 road-killed Snapping Turtles observed were sampled, these were arbitrarily collected and may be representative of the population. Loughry and McDonough (1996) found that road kills may be used for inferring the demography of adult armadillos (*Dasypus novemcinctus*). Both males and females, mature and immature comprised our sample. Males were more predominant prior to peak nesting. Male Snapping Turtles are generally active earlier in the spring than females (Kiviat 1980; Brown and Brooks 1993), possibly because they are searching for potential mates (Brown and Brooks 1993). This may account for their presence in the road-killed sample prior to nesting. Activity of females increases with the onset of nesting (Brown and Brooks 1993) as they search for oviposition sites; this accounts for their presence in the sample primarily during peak nesting. Juveniles were present throughout the study and possibly because there were dispersing from one wetland to another.

Galbraith et al. (1989) found that females first begin to lay eggs at 249 mm carapace length, corresponding to an age of 18 years. There were no mature females sampled less than 260 mm in this study. The smallest mature female was estimated to be 13 years by counting annuli on costal scutes, however, this should be considered a minimum age (Galbraith and Brooks 1987a, 1989; Lovich et al.

1990). The youngest mature male was estimated to be 14 years with a carapace length of 276 mm.

Snapping Turtles have high fidelity to nesting locations (Loncke and Obbard 1977; Obbard and Brooks 1980; Congdon et al 1987). Such fidelity suggests that adult female Snapping Turtles that were fortunate to avoid being killed one year, are highly vulnerable the following years. This may severely reduce the average longevity of adult turtles in the population and thereby also reduce the chances of successful reproduction (Congdon and Gibbons 1990).

The number of Snapping Turtles observed on the road side may be misleading in regard to the status of their population as being healthy. The fact that both mature and immature Snapping Turtles were the in sample suggests that recruitment is still occurring and therefore this study should be used primarily as a benchmark in terms of the number of Snapping Turtles along the road side in a point of time. The impact that road mortality is having on Snapping Turtle populations is unknown. There is no evidence that Snapping Turtle populations will exhibit a compensatory response to adult mortality by an increase in reproductive output, recruitment or juvenile growth rate (Brooks et al. 1991b). A decline in the population may therefore not be detected until effective replacement of the youngest age groups has virtually ceased (Congdon et al. 1987). So, I recommend that periodic surveys be conducted to monitor

the composition of the road side Snapping Turtle population.

This study has identified that Snapping Turtle road mortality may be relatively high on an annual basis in central Ontario and includes nesting females and mature males. This additional mortality may have negative implications not only to Snapping Turtle populations but other species of chelonians as well. Further studies should be conducted to determine the impact road mortality has to ensure that it does not result in the local extirpation of this or other species. During the interim, better public awareness is required on the possible ramifications that road associated mortality could have on Snapping Turtles and other susceptible species. In addition, more consideration is warranted during the planning process for the construction of roads, specifically through wetlands, and the long term impacts they could impose on the local fauna.

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Status of Goldenseal, *Hydrastis canadensis* (Ranunculaceae), in Canada*

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Although found throughout a large area of eastern North America south of the Great Lakes, the perennial woodland herb, Goldenseal (*Hydrastis canadensis* L.), was apparently only abundant in the central portion of its range in Ohio, West Virginia, Indiana, and northern Kentucky. In Canada, it is restricted to southwestern Ontario where 26 native populations have been reported representing the northern limit of its range. During a 1998 field survey, 21 populations were located, two were not surveyed, and the remaining three could not be found and are assumed extirpated. Attempts to discover additional populations with newly acquired ecological data failed suggesting that there are relatively few overlooked populations. Despite recent and rapid increase in the popularity of Goldenseal as an herbal remedy, there appears to have been little if any decline in Ontario populations since it was officially listed as threatened in 1991. Increasing use of the plant has increased the potential threat to Canadian populations and the actual global threat has also increased. Goldenseal generally occurs in isolated patches in slightly acid or neutral soil in rich mesic woodlands, often where disturbances such as tree removal or flooding have occurred. Restriction to isolated patches may be a consequence of loss of disturbance of the type caused by severe flooding of bottomland forests, fires, and impacts of extinct and extirpated fauna. Current research is aimed at understanding the limitations to its spread which may enable populations to be increased and facilitate development of a Canadian agricultural crop thus reducing pressure on natural populations.

Key Words: Goldenseal, *Hydrastis canadensis*, threatened, distribution, medicinal, wild harvest, population size, conservation status, agricultural crop, Ontario.

Goldenseal, *Hydrastis canadensis* L., (Figures 1 and 2) is a perennial woodland herb of eastern North America with its nearest relative in Japan. It is usually classified with the buttercups in the Ranunculaceae (Catling and Small 1994), but with some controversy. Its chromosome number, leaf anatomy, epidermal microcharacters, and floral, fruit, xylem and vessel morphology suggests placement in its own family, the Hydrastidaceae (Tobe and Keating 1985; Hoot 1991). The name Goldenseal is evidently derived from scars of previous annual stems (Figure 2) on its yellowish perennial rhizome that resemble wax seals once used on envelopes.

Goldenseal roots contain chemical alkaloids that have been used in antiseptics, laxatives, and anti-inflammatory agents for inflamed mucous membranes, and particularly in the treatment of digestive disorders, pneumonia, whooping cough, and diarrhea,

as it is said to benefit the gastrointestinal tract, bronchial tubes, nasal passages, and bladder. It has been used medicinally by a number of groups of eastern North American indigeneous people and by settlers since 1798 (Foster 1991). It became popular during the 1800s, has been one of the best selling plants on American herb markets over the past 20 years (Hobbs 1990), and has increased tremendously in popularity over the past several years. Research suggests a rational basis for some of the traditional uses (Foster 1991) but warnings about potential toxicity from overuse have been published (e.g. Hamon 1990; Health Canada 1995*). Goldenseal is currently marketed as an immune booster (e.g., Castleman 1991) and as a traditional herbal remedy to “enhance natural resistance to seasonal ailments and irritations” and to “strengthen and enhance overall health.” Goldenseal is taken mostly in the form of pills containing a mixture of medicinal herb ingredients. Wild populations of Goldenseal are currently under increasing pressure from harvest for domestic and international medicinal markets as a result of recent increase in its popularity and general increase in use of herbal medicines.

A rough-hairy perennial plant, Goldenseal (Figures 1 and 2) produces stems one to two feet high from a yellowish, horizontal, irregularly knotty

*This paper is based primarily on a COSEWIC status report update by the authors. The species was designated threatened by COSEWIC in 1991. Original COSEWIC reports are available from the COSEWIC Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada.

rhizome which measures 4–7 cm long and 0.5–2 cm wide when fresh. The 1–3 palmately lobed leaves, up to 25 cm in diameter, have 5–7 doubly-serrate lobes. The single flowers lack petals but have greenish-white sepals that separate and fall leaving numerous stamens and pistils. The fruit resembles a raspberry and contains shiny, dark brown or black, 2–2.5 mm long seeds each with a small keel.

Distribution

Goldenseal occurs from southern Vermont and southern Ontario to southern Wisconsin and south to Arkansas and northern Georgia (Figure 3). It was always most abundant in the central portion of its range in the states of Indiana, Kentucky, Ohio, and West Virginia (Lloyd and Lloyd 1908). In Canada, Goldenseal occurs only in southwestern Ontario (Figure 4). Symbols on the accompanying map (Figure 4) cover all reliable occurrences and are based on voucher specimens or photographs in various herbaria including CAN, DAO, TRT, HAM, WAT, UWO, and QK (acronyms from Holmgren et al. 1990). Twenty-six sites or populations (defined as 0.5 km apart) are known. These include: three areas (near Crediton in 1942, near Wingham in 1889, and near Varna in 1975) where it could not found in 1998 (triangles); two areas which could not be surveyed in 1998 (half dots); and 21 areas where populations were found in 1998 (full circles). A site near Durham in Grey County is a substantial disjunction and believed to be a result of introduction.

The 26 populations occur in nine major areas (Figure 4), mostly in the Carolinian Zone (Allen et al. 1990) which corresponds to the Lake Erie Lowland Ecoregion 135. The three northernmost populations occur in the southwestern portion of adjacent Manitoulin-Lake Simcoe Ecoregion 134 of the Mixedwoods Plains Ecozone (Ecological Stratification Working Group 1995).

Dore (1961) considered a record for Prescott, Grenville County, in eastern Ontario (Billings 1862), false because of lack of substantiating evidence: there is no specimen in the herbarium collection at Queens University (QK) where most of the specimens supporting Billings' early survey were deposited (Sinclair and Catling 1998a*).

The Ontario Rare Plants Atlas (White and Dickson 1983), the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) Status Report (White 1991*), and Catling and Small (1994) indicate a location for Goldenseal in Prince Edward County. Although there are numerous disjunct occurrences of essentially southern plant species at the eastern end of Lake Ontario (e.g., Brownell et al. 1994), this record is rejected. It was based on a collection preserved in the herbarium of the Royal Botanical Gardens at Hamilton (HAM). The collection was made in 1894 by J. R. Watson and labelled "Parma, O." Watson collected other

plants which are preserved at HAM and labelled similarly, e.g. "Baria, O.". We questioned the assumption that the "O." was for Ontario and J. Pringle (personal communication) confirmed that some of the plants from "Baria, O." included southern liliaceous species which do not occur in Ontario and he found that J.R. Watson lived in Baria, Ohio. Thus, the location "Parma, O." is Parma, Ohio, a city near Cleveland, rather than Parma in Lennox and Addington Co., Ontario.

Attempts to find new populations in 1998, using newly acquired ecological data failed (Sinclair and Catling 1998b*), suggesting that few populations have been overlooked.

Recent articles (Catling and Small 1994; Catling and Sinclair 1998) have alluded to the potential value of Goldenseal as a new Canadian agricultural crop. In this respect, it is of interest that cultivation has occurred north of its range in somewhat cooler parts of Ontario at Cornwall (45° 02' N, 74° 44' W) in Stormont County, and near Durham (44° 10' N, 80° 49' W) in Grey County.

Habitat

In southwestern Ontario, Goldenseal is limited to deciduous woodlands near floodplains and periodically spring-flooded plateaus. Only remnants of these woodland communities remain. Extreme southwestern Ontario forests have been reduced to less than five percent of what existed in pre-settlement times (Pearce 1997*), and occur as fragments within an agricultural and urban landscape. Associated species of vascular plants (scientific and common names from Newmaster et al. 1998) help to characterize the habitat and are listed in the following paragraphs.

Goldenseal colonies on upland sites occur on slightly acidic (pH 5.4 – 6.3) sandy loam or loam soils in fairly mature mesic woods under closed canopies. Dominant trees were Red Oak (*Quercus rubra* L.), Sugar Maple (*Acer saccharum* L.), and Hawthorn (*Crataegus* sp.), with Ash (*Fraxinus* sp.) and Shagbark Hickory (*Carya ovata* (Miller) K. Koch var. *ovata*). These upland woods populations are periodically spring-flooded. Topography is level with mounds and depressions. Species found most frequently with Goldenseal in quadrat samples, in order of decreasing frequency, were Woolly Blue Violet (*Viola sororia* Willd.), Cut-leaved Cranesbill (*Geranium maculatum* L.), False Solomon's Seal (*Maianthemum racemosum* (L.) Link ssp. *racemosum*), White Trillium (*Trillium grandiflorum* (Michx.) Salisb.), Wild Yam-root (*Dioscorea quaternata* J. Gmel.), Enchanter's Nightshade (*Circaea* spp.), Inserted Virginia Creeper (*Parthenocissus inserta* (A.Kern.) Fritsch.), Wild Leek (*Allium tricoccum* Aiton), Spotted Touch-me-not (*Impatiens capensis* L.), and Snakeroot (*Sanicula* sp.).



FIGURE 1. Goldenseal, *Hydrastis canadensis* L., photographed in Essex Co., Ontario, on 5 May 1998, by P. M. Catling.



FIGURE 2. Goldenseal, *Hydrastis canadensis*, L. flowering plant from a figure in the monographic study of Lloyd and Lloyd (1908).

Goldenseal colonies on lowlands and floodplains (Figure 5) occur on slightly acidic to slightly basic ($\text{pH} = 5.7 - 7.8$) clay or sandy loam soils in fairly mature dry mesic to mesic woods near rivers under closed to semi-open canopies. Dominant trees were Shagbark Hickory, Ironwood (*Ostrya virginiana* (Miller) K. Koch), and Basswood (*Tilia americana* L.), with Elm (*Ulmus* sp.) and Ash being common. These near-floodplain woods are periodically flooded during major flooding events. Topography is flat or a gradual slope to the water edge. Most near-floodplain sites are semi-open disturbed woodland edges between water and agricultural land where Raspberry (*Rubus* sp.), Spicebush (*Lindera benzoin* (L.) Blume), the introduced Common Barberry (*Berberis vulgaris* L.) and other introduced woody shrubs are common. Species found most frequently with Goldenseal in quadrat samples, in order of decreasing frequency, were Cut-leaved Cranesbill, Inserted Virginia Creeper, False Mermaid (*Floerkea proserpinacoides* Willd.), Spotted Touch-me-not, False Solomon's Seal, Enchanter's Nightshade, Trout Lily (*Erythronium* sp.), Snakeroot, Wild Leek, White Trillium, Wood Anemone (*Anemone quinquefolia* L. var. *quinquefolia*), and Wild Yam-root.

During a 1998 field survey, Sinclair and Catling (1998b*) found no evidence of extensive grazing nor of disease affecting Goldenseal. However, most sites were disturbed to a greater or lesser extent, through recreational paths, logging, or flooding. Several recently dug holes, about the size and depth of Goldenseal rhizomes, were found adjacent to existing Goldenseal plants at one site. Previous data on the number of stems at this site was not available. Goldenseal was found in disturbed portions of each site next to recreational paths, sloughs and drainage ways, in woodlot edges, previous flooding zones, thickets, and successional forests, and on riverbanks, constructed dikes, and logging roads, as well as in more pristine woodland. Probably as a consequence of occurrence in so many different habitats, Goldenseal was observed to have a remarkable number of different plant associates.

General Biology

Goldenseal reproduces from seeds but aerial stems develop from the perennial underground rhizome and roots. In late summer or early fall, a new bud is

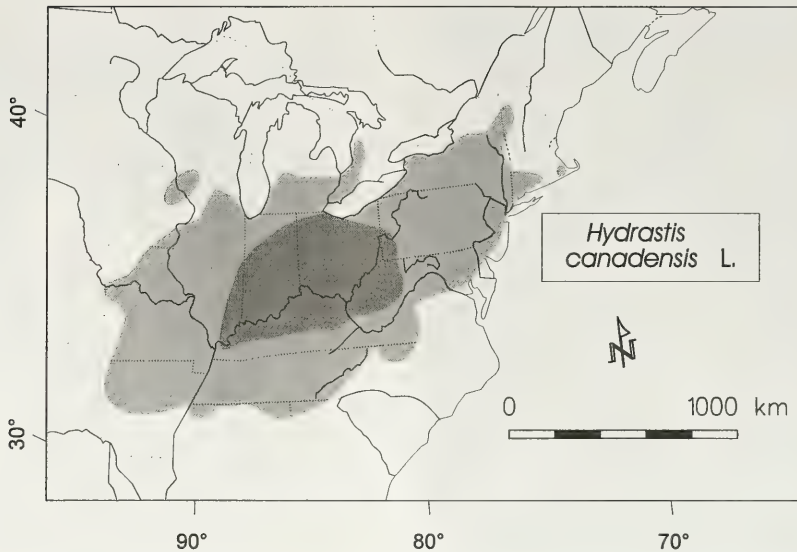


FIGURE 3. Distribution of Goldenseal (*Hydrastis canadensis*, L.) in North America adapted from Catling and Small (1994) and originally based on Lloyd and Lloyd (1908); Radford, et al. (1964); Crow (1982); Good (1978)*; Porter (1979); Mitchell and Sheviak (1981); and Voss (1985).

produced on the rhizome from which a stem grows during the following year. The stem emerges in April, its leaves unfold, and flowers open during stem elongation and leaf expansion in late April and May in southwestern Ontario. The flower has no petals but has sepals that usually fall away as soon as the bud opens. The numerous extended stamens and pistils (Figures 1 and 2) are greenish-white. The conspicuous mass of stamens suggests pollination by pollen gathering bees. Leaf expansion and fruit growth follows. Most leaves are fully expanded by June. The bright red, raspberry-like fruit develops and ripens from July to the beginning of August. We observed fruiting from 4 to 19 July at which time 18 percent of fruit were unripe, 73 percent were ripe, and nine percent were over-ripe. In 10 out of 17 populations, 60 to 100 percent of flowering stems produced fruit. In the seven other populations, only 10 percent, or less, of flowering stems produced fruit (Sinclair and Catling 1998b*). Fruit disappeared shortly after ripening. Fallen berries were seen at the base of only two stems. The colour, top position, and rapid disappearance of the fruit suggests dispersal by birds. After berries mature, root growth is more pronounced and buds of next year's stem begin to develop on the rhizome (Eichenberger and Parker 1976). Plant senescence begins and the stem dies in mid-September to late October due to frost.

Population Size and Trends

Twenty-six native populations of Goldenseal are known in Canada. Populations are defined as groups

of potentially cross-pollinating plants no less than 0.5 km apart. The 1998 field survey of 26 populations verified 21 extant and suggested three extirpated populations near Wingham, Varna, and Crediton (Sinclair and Catling 1998a*, 1998b*). Populations consist of either a single patch or several dense patches over a distance up to 300 m, and in a few cases include scattered individuals. Eleven out of 20 censused populations consisted of one or two patches in areas no larger than 2 m². Five of the 20 censused populations consisted of three to eight patches within a distance of 50 to 300 m. One population consisted of several small patches in a 5 × 15 m area. Three populations consisted of single dense large patches: one occupying an area of about 10 m² and two occupying areas of about 40 m² (Sinclair and Catling 1998b*).

Due to the clonal nature of this plant, it is difficult to estimate the number of plants contained within each population; therefore, Sinclair and Catling (1998a*, 1998b*) counted the number of stems as an estimate of population size. Four populations had less than 50 stems; seven populations had 100–300 stems; two populations had 400–500 stems; three populations had 600–800 stems; one population had just over 1000 stems; and one population had over 4000 stems. It is important to note that these numbers almost certainly do not represent genetically distinct plants. They may represent a few to several clones each of which may have dozens or hundreds of flowering stems.

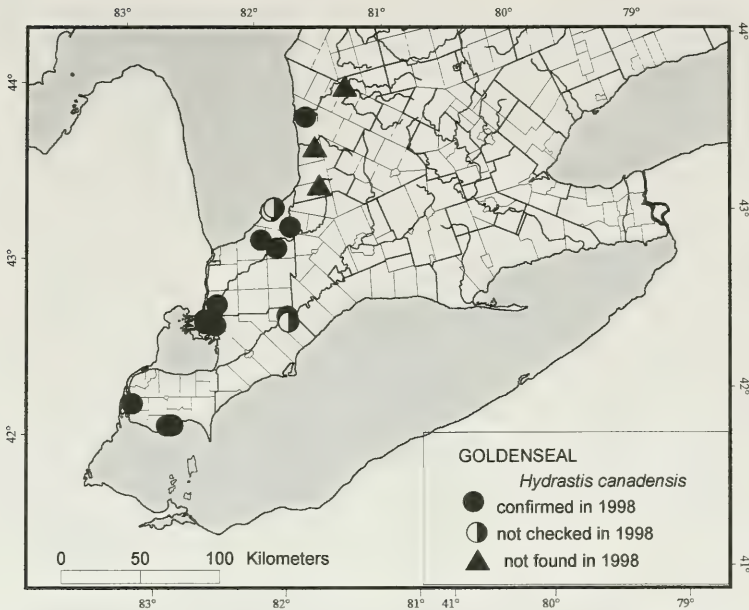


FIGURE 4. Distribution of Goldenseal (*Hydrastis canadensis*, L.) in southwestern Ontario based on specimens at CAN, DAO, TRT, HAM, WAT, UWO, and QK (acronyms from Holmgren et al. 1990). Triangles indicate areas (near Crediton in 1942, near Wingham in 1889, and near Varna in 1975) where it was not found in 1998; half dots indicate areas which could not be surveyed in 1998; and solid dots indicate areas where populations were found in 1998.

To the extent that small plants become large plants and large plants become flowering plants which persist, size class ratios suggest that some patches may be rapidly increasing in size whereas others may not. In a few cases where plants were excavated, small stems had developed from roots of larger plants and most large stems had developed from large rhizomes. These large rhizomes had produced either large or flowering stems previously as evidenced by scars (Sinclair and Catling 1998b*).

The 1998 survey suggests that there has been little if any decline in Canadian populations since 1991 (Sinclair and Catling 1998b*). Within populations there may have been an increase in numbers of patches and stems, but the original census data was not collected in such a way as to provide a basis for future comparisons. Consequently, an increase in population size is not proven, but nor is there any fully reliable evidence for decline. Stability or possible increase in patch size seems most likely (Sinclair and Catling 1998a*). Populations of Goldenseal appear to be healthy; however, they do not appear to be spreading by seed at many sites. In these sites, Goldenseal occurs only in isolated patches and evidence of seedling development was not found. A portion of an isolated patch, including 191 stems, is shown in Figure 5. Populations do not stretch out over large

areas and become dominant in the forest understorey. Patches covering up to 40 m² occur at several sites suggesting that they have been established for a relatively long period, but satellite plants and patches suggestive of spread by seed were not evident.

Limiting Factors

Based on analysis of productivity and environmental data collected by the authors in 1998, it appears that Goldenseal has few environmental constraints. Only three environmental variables had significant effect on Goldenseal productivity. Number of young plants increased with increasing phosphorous (Sinclair and Catling 1998b*), suggesting that establishment and development of young stems may be promoted by high levels of nutrients. Number of Goldenseal stems decreased with increasing woodlot size (Sinclair and Catling 1998b*), suggesting that Goldenseal may be independent of some ecological characteristics of larger woodlots such as provision of adequate space for animal populations and territories, increased connectivity of a larger number of microhabitats, and reduced edge effects. There is evidence that Goldenseal responds to increased competition in terms of plant associate cover by producing more fruit of larger size (Sinclair and Catling 1998b*). The observation of Goldenseal plants and

patches in disturbed woodlots and disturbed portions of pristine woodlots, along with implied benefits of increasing phosphorous and a negative effect of increasing woodlot size, suggests that disturbance such as flooding, fire, etc., may be beneficial to growth and spread.

Although Goldenseal is productive, able to expand in patch size, often dominates plant cover in its patches, and appears to have general environmental requirements, it often occurs only in isolated patches suggesting a limitation to spread. The question naturally arises as to why it does not locally saturate the available habitat like so many other woodland herbs (e.g., White Trillium, Cut-leaved Crossbill, Trout Lily, and Wild Leek), since it appears to be able to displace other species from a patch. Presumably there is a limit to its spread that involves dispersal and/or colonization.

Spread of Goldenseal may require organisms to disperse fruit and/or disturbance by organisms or events that no longer occur in its habitat to a substantial degree. The present patchy distribution may be a consequence of loss of natural processes such as severe flooding of bottomland forests, fire, and faunal impacts. Passenger Pigeons (*Ectopistes migratorius* L.), Black Bears (*Ursus americanus* Pallas), and various pleistocene mammals (Kurtén and Anderson 1980), now extinct or extirpated, may have opened the canopy and/or disturbed the soil and possibly provided nutrients and contributed to dispersal (e.g. Tardiff and Stanford 1998). This fauna was present in northeastern forests prior to extensive settlement by Europeans and even prior to the melting of the Wisconsin glacier approximately 12 000 years ago.

Management involving simulation of specific natural processes may provide conditions necessary for successful seedling establishment thereby, enabling Goldenseal to spread where it still occurs and re-establish in areas where it has disappeared. Although simulation of these natural processes in woodland habitats may promote Goldenseal, it is a complex management option since disturbance also promotes competitive invasive alien plant species and varies greatly in type and degree. Although disturbance of a certain type may promote Goldenseal, this does not mean that Goldenseal should increase due to increasing disturbance to natural vegetation on the landscape. To the contrary, vital elements of previous natural processes may no longer exist and there is a continuing decline in proportion of the landscape affording potentially appropriate habitat. Ongoing research is aimed at the development of a recovery plan including consideration and testing of management options (Sinclair and Catling 1998b*).

In addition to spread and dispersal, survival of Goldenseal populations is threatened by collecting. Native populations are currently under increasing pressure from harvest in the United States for

domestic and international medicinal markets (USFWS 1997*; Robbins 1996; IUCN 1997*). Collecting of rootstocks from isolated colonies, where spread by seed is limited, would quickly eradicate populations. Fortunately, evidence of harvest was seen at only one of 21 Ontario sites by the authors in 1998 but harvest is increasingly a problem in the United States range (USFWS 1997*; IUCN 1997*).

Survival of Goldenseal populations may also be threatened by development. Clearing woodlots for residential construction apparently is a threat to populations in upland sites which are all privately owned. Lots have been cleared in some of these sites recently. Populations near floodplains are less threatened as further agricultural encroachment in these areas seems unlikely due to unsuitable moisture regime or topography. Only four of thirteen floodplain sites are privately owned and most of the larger forest remnants that have not been reduced to edges are owned and managed by conservation authorities.

Special Significance

The popularity of Goldenseal as a medicinal herb is rapidly increasing. The medicinal plant market as a whole, as well as demand for Goldenseal, has experienced in excess of a 30 percent growth rate in the last two years alone (USFWS 1997*). Goldenseal is present in numerous drug products in Canada (Catling and Small 1994) and in 1994, it was the second most popular herb purchased by consumers in the United States (Robbins 1996). Wholesale value of Goldenseal in the United States has increased by as much as 600 percent in the last five years (Robbins 1996). It is well known on international markets as well. For example, it is currently available in a wide array of herbal products in France, Australia, Germany, United Kingdom, Italy, and other European countries (Robbins 1996; Oddo et al. 1996*; IUCN 1997*). Consumption levels of Goldenseal are likely to increase in the future (IUCN 1997*). Herb products are now considered "dietary supplements", the market for which is expected to increase by 400 percent by the year 2000.

Due to its growing value for commercial trade, there is potential to use Goldenseal for a diversification crop in Canada (Catling and Small 1994), which could reduce unsustainable harvest of wild populations. Native Canadian populations contain characteristics, including local climate and pest adaptation, as well as genetic variation necessary to develop a viable Canadian agricultural crop. Goldenseal was recently highlighted as a priority species for protection in Canada based on economic significance (Catling and Porebski 1998). It has been cultivated in the United States (Anderson et al. 1926; Davis 1996; Fleet 1916; Henkel and Klugh 1908), especially in the early 1900s, and has recently been promot-



FIGURE 5. Goldenseal accompanied by Cut-leaved Cranesbill (*Geranium maculatum*), False Mermaid (*Floerkea proserpinacoides*), Enchanter's Nightshade (*Circaea* sp.), False Solomon's Seal (*Maianthemum racemosum* ssp. *racemosum*), and Inserted Virginia Creeper (*Parthenocissus inserta*) in a woodland dominated by Shagbark Hickory (*Carya ovata* var. *ovata*) and Red Oak (*Quercus rubra*) with Red Maple (*Acer rubrum*) and Ironwood (*Ostrya virginiana*) in Essex Co., Ontario. Photo by P. M. Catling, 5 May 1998.

ed in British Columbia (Li and Oliver 1995) as a plant with cultural requirements similar to those of Ginseng (*Panax quinquefolius* L.).

Research on limiting factors to population growth may produce results applicable to other endangered and threatened woodland plants and thus suggest

similar recovery actions. Ecological experiments applied to Goldenseal may be applicable to other species and used as a model for testing requirements of other plants. A conservation strategy for Goldenseal may apply to the total plant community of which it is part and there is currently little infor-

mation on the significance and function of plants like Goldenseal in the deciduous forest ecosystem.

Consequently, Goldenseal is significant with respect to human health and economy as well as to the management and protection of biodiversity.

Protection

Virtually all Goldenseal on the market is supplied from the wild. Management policies for wild populations are lacking due to limited information on both its population ecology and general environment (White 1991*; USFWS 1997*). As a result, Goldenseal was added to Appendix II of CITES (Convention on International Trade in Endangered Species) 8 June 1998 (WWF-US 1998*). There is no other formal legal protection.

Sixty-five percent of Canadian Goldenseal populations is in private ownership. The other 35 percent occurs on conservation authority property. The largest population (>4000 stems) is under private ownership. Four of the larger populations (>500 stems) are under protective ownership of conservation authorities (Sinclair and Catling 1998a*, 1998b*). No formal management or protective agreements have been made concerning Goldenseal. To date, landowners have permitted mapping and study of populations, providing an initial framework for, and step towards, long-term management.

Since 13 Goldenseal sites (i.e., more than half) are solely under private ownership and management, maintenance of a well informed network of landowners is crucial to protect and recover Goldenseal. The mixture of private and public landowners is potentially advantageous in protecting plants from wild harvest, since public access to private lands is more restricted, especially in southwestern Ontario where trespassing is conspicuous. Furthermore, some private landowners have a strong commitment to conservation. Due to the increasing popularity of Goldenseal for medicinal use, maintenance of a well informed public is also crucial to protect and recover Goldenseal.

To date, there has been very limited information on the population ecology or required habitat conditions of Goldenseal (White 1991*; USFWS 1997*); thus, habitat management for Goldenseal has not been undertaken in Canada. Likewise, in the United States, there are no comprehensive programs to manage populations of Goldenseal or to ensure a sustainable regeneration from utilisation (USFWS 1997*).

In the United States, Goldenseal is considered either critically imperiled, imperiled, uncommon, or rare in all 27 states having native populations (Robbins 1996; USFWS 1997*; Bill Mabon, personal communication 1998). There is no scientifically valid guideline for ethical and sustainable harvesting in the wild. Statements by herbal companies that Goldenseal has been "ethically wildcrafted" or the

assurance that such is the case by having collectors or sellers sign a document to this effect is scientifically indefensible at this time (USFWS 1997*).

Evaluation of Status

In the 1991 status report, White noted that "unless harvesting of the plant resumes, ... the species should suffer no major population decline". Harvesting has resumed in portions of the United States range and has caused rapid decline locally (USFWS 1997*). Although harvesting was recently observed at only one of 21 locations in Ontario, potential threat of future harvesting in Ontario has increased greatly due to the growing popularity of Goldenseal as a medicinal herb. Annual monitoring, combined with management and recovery planning, is desirable due to the level of potential threat. Goldenseal is an unusual case as a threatened species: although it has apparently not declined in Canada since 1991, potential threat to Canadian populations is increasing and actual threat has increased within the main (United States) range (Sinclair and Catling 1998a*).

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First Record of a Freshwater Drum, *Aplodinotus grunniens*, in the Rideau River, Ottawa, Ontario

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Phelps, Anne, Claude B. Renaud, and François Chapleau. 2000. First record of a Freshwater Drum, *Aplodinotus grunniens*, in the Rideau River, Ottawa, Ontario. *Canadian Field-Naturalist* 114(1): 121–125.

A Freshwater Drum, *Aplodinotus grunniens*, family Sciaenidae, captured in the Rideau River, Ottawa, Ontario, on 28 July 1998, is the first reported capture of this species within the Rideau River. It increases the total number of fish species reported in the Rideau River and Canal to 56 species belonging to 19 families.

Key Words: Freshwater Drum, *Aplodinotus grunniens*, Rideau River, Ottawa.

A survey of the Rideau River fish community was conducted during the summer of 1998 as a part of the Rideau River Biodiversity Project, involving the Canadian Museum of Nature, the Rideau Valley Conservation Authority, and the University of Ottawa. As a result of this survey, a Freshwater Drum, *Aplodinotus grunniens* Rafinesque, was captured in the Rideau River, between the Bank Street and Bronson Street bridges, Ottawa, Ontario (45° 23' 12"N, 75° 41' 09"W), by Anne Phelps and Brent Campbell on 28 July 1998 (Figure 1). This is the first reported capture of a Freshwater Drum within the Rideau River (Figure 2). The site of capture on the Rideau River is approximately 9 km upstream from its confluence with the Ottawa River, Rideau Falls. The base of Rideau Falls is the Freshwater Drum's nearest known site in the Ottawa River. The

Rideau River record is 208 km from its nearest known site in the St. Lawrence River, Browns Bay, and 220 km from its nearest known site in Lake Ontario, the Bay of Quinte (Mandrak and Crossman 1992). According to literature records (Small 1883; Prince et al. 1906; Halkett 1906, 1908; Dymond 1939; McAllister and Coad 1974; Coad 1983, 1987; City of Gloucester 1991*, 1992*; and RMOC 1995a*, 1995b*, 1996a*, 1996b*, 1998*), 56 fish species (including the introduced Brown Trout, *Salmo trutta*, Rainbow Trout, *Oncorhynchus mykiss*, and Common Carp, *Cyprinus carpio*) belonging to 18 families have been reported in the Rideau River and Canal (Table 1). The discovery of the Freshwater Drum in the Rideau River increases these numbers to 57 species belonging to 19 families. For comparison, 64 species from 21 families have been



FIGURE 1. Side-view of Freshwater Drum, *Aplodinotus grunniens*, 461 mm standard length, captured in the Rideau River on 28 July 1998 (Canadian Museum of Nature catalog number CMNFI 1999–4).

TABLE 1. List of fish species reported in the Rideau River and Canal according to literature records since 1883. *Captured during the 1998 field season. #First reported in this paper. †Found previous to survey but unpublished until Pheleps et al. (2000). An additional introduced species was recorded in 1999 (Renaud and Phelps 1999) [see addendum references]. Scientific names according to Robins et al. (1991).

Family	Scientific Name	Common Name
Petromyzontidae	<i>Ichthyomyzon unicuspis</i>	Silver Lamprey
Lepisosteidae	<i>Lepisosteus osseus</i>	Longnose Gar
Anguillidae	<i>Anguilla rostrata</i>	American Eel
Clupeidae	<i>Alosa pseudoharengus</i>	Alewife
Salmonidae	<i>Oncorhynchus mykiss</i>	Rainbow Trout
	<i>Salmo trutta</i>	Brown Trout
Esocidae	<i>Esox lucius</i> *	Northern Pike
	<i>Esox masquinongy</i> *	Muskellunge
Umbridae	<i>Umbra limi</i>	Central Mudminnow
Cyprinidae	<i>Cyprinus carpio</i> *	Common Carp
	<i>Hybognathus hankinsoni</i>	Brassy Minnow
	<i>Hybognathus regius</i>	Eastern Silvery Minnow
	<i>Luxilus cornutus</i> *	Common Shiner
	<i>Margariscus margarita</i>	Pearl Dace
	<i>Notemigonus crysoleucas</i> *	Golden Shiner
	<i>Notropis atherinoides</i> *	Emerald Shiner
	<i>Notropis heterodon</i> *	Blackchin Shiner
	<i>Notropis heterolepis</i> *	Blacknose Shiner
	<i>Notropis hudsonius</i> *	Spottail Shiner
	<i>Notropis rubellus</i>	Rosyface Shiner
	<i>Notropis volucellus</i>	Mimic Shiner
	<i>Phoxinus eos</i>	Northern Redbelly Dace
	<i>Phoxinus neogaeus</i>	Finescale Dace
	<i>Pimephales notatus</i> *	Bluntnose Minnow
	<i>Pimephales promelas</i>	Fathead Minnow
	<i>Rhinichthys cataractae</i>	Longnose Dace
	<i>Semotilus atromaculatus</i>	Creek Chub
	<i>Semotilus corporalis</i> *	Fallfish
Catostomidae	<i>Catostomus commersoni</i> *	White Sucker
	<i>Moxostoma anisurum</i> *	Silver Redhorse
	<i>Moxostoma macrolepidotum</i>	Shorthead Redhorse
	<i>Moxostoma valenciennesi</i> *	Greater Redhorse
Ictaluridae	<i>Ameiurus natalis</i>	Yellow Bullhead
	<i>Ameiurus nebulosus</i> *	Brown Bullhead
	<i>Ictalurus punctatus</i>	Channel Catfish
	<i>Noturus flavus</i>	Stonecat
	<i>Noturus gyrinus</i> †*	Burbot
Gadidae	<i>Lota lota</i>	Burbot
Percopsidae	<i>Percopsis omiscomaycus</i>	Trout-Perch
Cyprinodontidae	<i>Fundulus diaphanus</i> *	Banded Killifish
Atherinidae	<i>Labidesthes sicculus</i> *	Brook Silverside
Gasterosteidae	<i>Culaea inconstans</i>	Brook Stickleback
Centrarchidae	<i>Ambloplites rupestris</i> *	Rock Bass
	<i>Lepomis gibbosus</i> *	Pumpkinseed
	<i>Lepomis macrochirus</i> *	Bluegill
	<i>Micropterus dolomieu</i> *	Smallmouth Bass
	<i>Micropterus salmoides</i> *	Largemouth Bass
	<i>Pomoxis nigromaculatus</i> *	Black Crappie
Percidae	<i>Etheostoma exile</i>	Iowa Darter
	<i>Etheostoma nigrum</i>	Johnny Darter
	<i>Etheostoma olmstedti</i> *	Tessellated Darter
	<i>Perca flavescens</i> *	Yellow Perch
	<i>Percina caprodes</i> *	Logperch
	<i>Stizostedion canadense</i>	Sauger
	<i>Stizostedion vitreum</i> *	Walleye
Sciaenidae	<i>Aplodinotus grunniens</i> **	Freshwater Drum
Cottidae	<i>Cottus bairdi</i> *	Mottled Sculpin

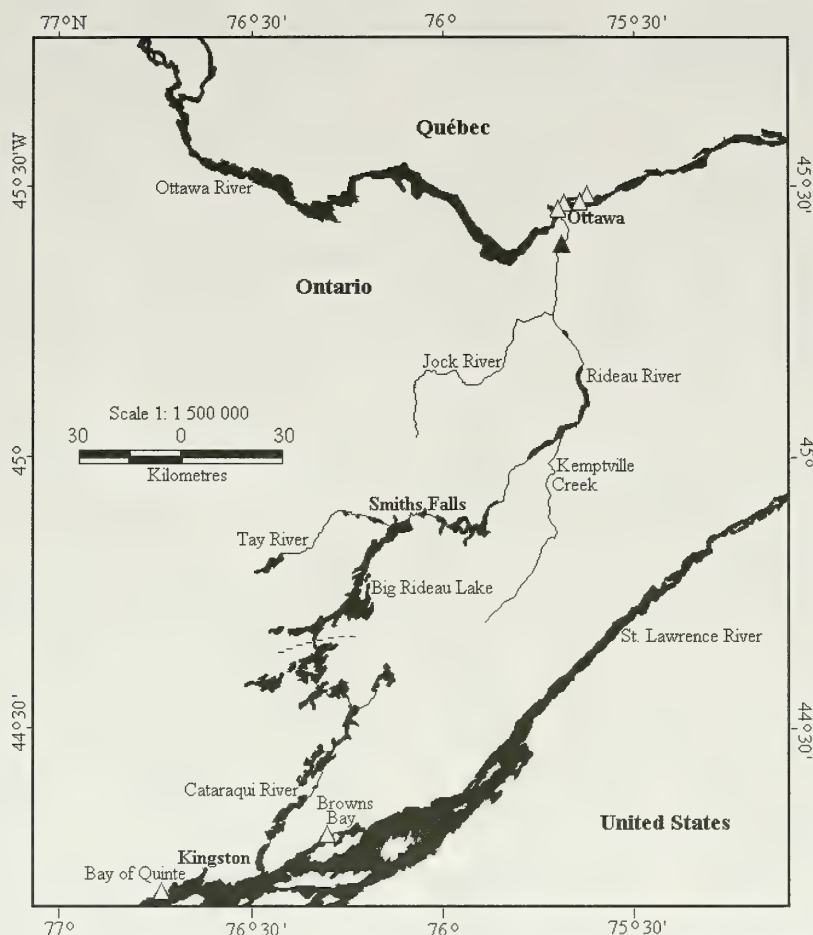


FIGURE 2. Distribution map for the Freshwater Drum, *Aplodinotus grunniens*, in eastern Ontario. The black triangle indicates the new Rideau record, the white triangles indicate past records within the region. The dashed line indicates the divide between the Rideau and the Cataraqui rivers, which together constitute the Rideau River Canal System.

reported for the Ottawa River (Dymond 1939; McAllister and Coad 1974; Coad 1987).

The freshly captured Freshwater Drum measured 461 mm in standard length, 568 mm in total length and weighed 2.76 kg. The specimen is beyond the average range of total lengths for a Freshwater Drum, 457-508 mm (Scott and Crossman 1973). External and internal examination did not reveal the presence of parasites. A radiograph did not reveal any skeletal abnormalities. The Freshwater Drum, a female, was 13 years old, as determined from scale samples taken from the right side, above the lateral line just below the origin of the dorsal fin and behind the pectoral fin. Scale impressions were made onto acetate slides and read twice by two individuals in addition to the authors. All individuals agreed on the age determination. Annuli were ascertained accord-

ing to three criteria: the discontinuous ridges (circuli) were located between two continuous ridges (annuli), the cutting over of the ends of outcurved ridges by new ridges, and the crowding of circuli (Lagler 1949). The Freshwater Drum's digestive system was empty due to the length of time spent in the trapnet. The fish has been deposited in the collection at the Canadian Museum of Nature (catalog number CMNFI 1999-4).

The Freshwater Drum was captured in a trapnet with a 1.83 m³ box, a multifilament stretched mesh size of 6.4 cm, and a 25 m × 1.83 m multifilament lead. The lead was attached to the shore with the net spanning approximately half the width of the river, perpendicular to the current. River width at this location was 60 m, and the river depth at the opening of the box was 3.5 m. The net was set for 24 hours.

Other species caught in the same trapnet on that day include one Northern Pike (*Esox lucius*), eight specimens of Common Carp (*Cyprinus carpio*), one Silver Redhorse (*Moxostoma anisurum*), two Rock Bass (*Ambloplites rupestris*), and five Smallmouth Bass (*Micropterus dolomieu*). The shoreline vegetation was primarily long grass with few overhanging trees, bordering an area of urban development. There was a shopping centre on the eastern side of the river and parkland on the other. Aquatic vegetation covered approximately 20% of the bottom and consisted of mostly Wild Celery, *Vallisneria americana*, and some Water Milfoil, *Myriophyllum* species. The substrate type was 75% sand, 15% rubble, and 10% large woody debris. The water temperature was 24°C at 20 cm from the surface.

The Freshwater Drum is the only freshwater species of the family Sciaenidae in North America (Barney 1926; Robins et al. 1991) and has the greatest latitudinal range of any of the North American freshwater fishes (Fremling 1980). It has large molariform pharyngeal teeth well adapted for crushing mollusc shells (French 1997). The diet of individuals greater than 250 mm in total length consists of larval dipterans, cladocerans, and fishes, with pelecypods (native bivalve molluscs) and decapods (crayfishes) added to the diet of individuals over 350 mm in total length (Bur 1982). Within the last decade, the exotic Zebra Mussel, *Dreissena polymorpha*, has also become an important food item for Freshwater Drum inhabiting the Great Lakes (French and Bur 1993; Morrison et al. 1997).

The southernmost extension of the Freshwater Drum's range spans the coast of the Gulf of Mexico through eastern Mexico to the Rio Usumacinta Basin of Guatemala. In the United States, it is found throughout the Mississippi drainage basin (Fremling 1980). In Canada, the Freshwater Drum is found in southern Saskatchewan, throughout Manitoba as far north as Hudson Bay, in southern and eastern Ontario, and in southern and western Quebec (Scott and Crossman 1973). In Ontario, it is found in the St. Lawrence River, the Ottawa River, Lake Abitibi, and the Great Lakes, except Superior (Mandrak and Crossman 1992). In the Ottawa area, the Freshwater Drum is not commonly captured. Small (1883) stated that the Freshwater Drum was not prevalent in the Ottawa River although several were captured near Templeton in 1882. Dymond (1939) noted that the species was found in the Ottawa River upstream and downstream of the Chaudière Falls. McAllister and Coad (1974) reported two specimens captured by P. Rubec in the Ottawa River; one off the western tip of Upper Duck Island in July 1972 and the other off the western tip of Kettle Island in August 1972 (Canadian Museum of Nature catalog number NMC72-142 and 72-143). No other records were reported for the Ottawa region until June 1984 when

L. Jutasi and C. Szabo captured two specimens in the Ottawa River at the base of Rideau Falls (NMC84-257). In the present study, between the 20 July and the 10 September 1998, over 6900 fishes were captured in the Rideau River using seines, hoopnets, trapnets, and backpack electrofishing. Of that total, 332 fishes, including the Freshwater Drum specimen, were caught in 14 trapnets set for 24 hours each.

The natural outlet of the Rideau River is a 15 m drop, Rideau Falls, an impassable barrier to the movement of fishes from the Ottawa River to the Rideau River. However, the construction of locks along the length of the Rideau Canal System between 1826-1832 have made access possible from both the Ottawa River and the Lake Ontario — St. Lawrence River. If the Freshwater Drum had strayed into the Rideau River from Lake Ontario — St. Lawrence River it would have traveled through 33 locks, upstream through the Cataract River, then downstream through the Rideau River towards Ottawa. This is what has occurred in the case of the Alewife, *Alosa pseudoharengus* (Coad 1983). If the Freshwater Drum had strayed in from the Ottawa River it would have traveled upstream through only 12 locks. The available data do not permit us to establish which of the two possible scenarios has occurred. However, it is clear that the creation of the Rideau River Canal System has made possible the movement of fishes from other watercourses.

Acknowledgments

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Addendum

Additional references to Table 1 (published subsequent to original submission).

- Phelps, Anne, François Chapleau, and Claude B. Renaud.** 2000. The Tadpole Madtorn, *Noturus gyrinus*: A rarely seen fish of the Rideau River System, Ontario. *Trail & Landscape* 34(1): 30-34.
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Alien and Invasive Native Vascular Plants Along the Norman Wells Pipeline, District of Mackenzie, Northwest Territories

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Vegetation studies were carried out as part of a research and monitoring program to evaluate project effects and the performance of environmental mitigation along the Norman Wells to Zama Pipeline. This was the first fully buried oil pipeline and the largest and most extensive revegetation program to date in the boreal forest — discontinuous permafrost zone of the Northwest Territories. The pipeline owners (Interprovincial Pipe Line (NW) Ltd. (IPL), now Enbridge Pipelines Inc.) developed a special combination of seeds composed of predominantly native North American species from certified seed stocks to help reduce the risk of introduction of alien (non-North American) species. Monitoring, primarily focussed on the pipeline construction period, confirmed the initial presence of a limited number of alien species. The purpose of this paper is to update floristic data for the Continental Northwest Territories and document invasion of alien plants despite mitigative measures. Of the 34 alien taxa collected along the pipeline right-of-way, 15 are new to the flora of the mainland Northwest Territories including *Agrostis stolonifera*, *Alopecurus arundinaceus*, *Alopecurus pratensis*, *Bromus commutatus*, *Bromus hordeaceus*, *Bromus squarrosus*, *Festuca trachyphylla*, *Festuca valesiaca* ssp. *sulcata*, *Lolium perenne* ssp. *perenne*, *Lolium perenne* ssp. *multiflorum*, *Poa annua*, *Secale cereale*, *Triticum aestivum*, *Vulpia bromoides*, and *Corispermum orientale* var. *emarginatum*. Nineteen alien taxa previously known from other areas of Continental Northwest Territories including the aggressive weedy grass known as Cheatgrass or Downy Brome are also reported. Thirteen native North American taxa of invasive habit, but uncommon in the Continental Northwest Territories were also detected along the pipeline.

Key Words: alien vascular plants, revegetation, Norman Wells Pipeline, District of Mackenzie, Northwest Territories, Mackenzie Valley.

The Norman Wells Pipeline Project involved the most extensive revegetation program to date in the mid-high boreal forest, including subarctic forest, of the western Northwest Territories (N.W.T.). The 869 km long (540 mi) pipeline is the first completely buried oil pipeline in the discontinuous permafrost zone in Northern Canada where it traverses erodible mineral and organic terrain, including both icy “thaw-sensitive” and “warming-sensitive” permafrost terrain from Norman Wells, N.W.T., to Zama, Alberta, (Figure 1a and b, 751 km in N.W.T.). Pipeline operations commenced in April 1985 (a 324 mm (12.7 inch) diameter pipe designed for ~30 000 barrels per day), following primarily winter construction in 1983–84 and 1984–85. Overland access for maintenance is seasonally limited. Vegetation assisted erosion control is necessary especially in the ice-rich permafrost terrain where ground thaw settlement causes surface elevation and subsequent drainage changes. The pipeline owner/operator, Interprovincial Pipe Line (NW) Ltd. (IPL) (now Enbridge Pipelines Inc.) has examined the success of revegetation from an erosion control perspective and undertook remedial work where necessary.

The project included major new, as well as standard, approaches to pipeline design and environmental impact mitigation such as minimizing the length of the pipeline in thaw-sensitive, or warming-sensitive, terrain; minimizing the energy input from the pipeline to ice-rich terrain; maximizing the length of the pipeline in previously cleared or disturbed areas; and, using primarily winter construction when much of the alignment was protected by frozen ground and snow or ice ground cover (ESSO and IPL 1980; MacInnes et al. 1989, 1990). One of the authors (K. L. MacInnes) was involved in evaluating the impacts and success of various mitigative measures, including the ecological implications of the revegetation program.

IPL's pipeline revegetation was undertaken primarily to reduce erosion by decreasing the velocity of surface water movement and by reducing volumes of subsurface water through evapotranspiration. Initial design plans for revegetation called for selection of basic seed mixes (Appendix 1) consisting of five to seven species of grasses known to do reasonably well under northern conditions and covering a range of soil and moisture conditions with

growth/development rates for short and long term ground cover establishment (Wishart and Fooks 1986; Wishart 1988).

The initial plans included seeding of mineral soils only (defined here as any soils where ditching exposed mineral soils) using a relatively conservative application of seed (compared to the trans-Alaska pipeline: Johnson 1981) depending on the erosion potential of the site (50 kg/ha or 30 kg/ha). Seedbed preparations and initial post-construction seeding took place in winter using hand and vehicle pulled cyclone seeders. Initial seeding was planned for a 10 m width strip centred over the pipe but because of additional disturbance the seeding was usually extended to the 20-25 m tree-cleared pipeline right-of-way. The areas of federal crown land in the Northwest Territories used under easement and temporary land use permits for the construction of the pipeline through September 1985 totalled 2597 hectares, of which the major portion consisted of right-of-way utilization (1797 ha).

The seeds to be used were specified by IPL, ordered in individual lots from a variety of North American and European producers, and put together into a specially designed mix for the Norman Wells Pipeline. Seeds were checked for purity and weed content as part of the Canadian seed certification program and IPL supplied Seed Certificates and reports, as required, on the revegetation programs. IPL monitored the success of their revegetation during and immediately after construction in erosion prone and other new maintenance areas. Additional remedial reseeding has taken place annually using the original "IPL mixes" as long as supplies lasted and more recently with commercially available seed mixes that included grasses that were known to grow well on the right-of-way. The observations discussed here focus on the 751 km of pipeline right-of-way in N.W.T. including areas which were reseeded in 1986-1988. Summer (thaw-season) monitoring was monthly from May to October in 1984-1986 primarily by helicopter. Stopping points for collections included revegetation trial areas established by the Department of Indian and Northern Affairs (DIAND) with IPL cooperation, study sites for the ground and pipe thermal monitoring, slopes, water crossings and other areas (settlement, erosion, pipe exposures, etc.) Regular but decreasingly frequent observations have continued through to September 1995. Following the initial finding of the aggressively weedy grass, Downy Brome (*Bromus tectorum*) and the disease head smut (*Ustilago bullata*) on the primary component of the seed mix, Slender Wheat grass (formerly *Agropyron trachycaulum*, now called *Elymus trachycaulus*), increased emphasis was placed on the collection of these species and diseased specimens (Cody and MacInnes 2000). The purpose of this paper is to update floristic data for the Continental

Northwest Territories and document invasion of alien plants despite mitigative measures.

Annotated list by family

In this list the pipeline distance from Norman Wells is in **bold**, followed by the year in which the collection was made and the number or designator assigned to the individual specimen. Genera and species are listed alphabetically under families and nomenclatural synonyms are indicated in parentheses. Alien (non-North American) taxa new for the Continental Northwest Territories are marked with an asterisk (*).

All plant collections (1984-1989) and field observations (1983-1995) were made by Kaye MacInnes in connection with regular monitoring of the Norman Wells Pipeline Project area for the Department of Indian Affairs and Northern Development. All specimens cited were deposited at the Vascular Plant Herbarium of Agriculture and Agri-Food Canada, Ottawa (DAO). Location, date and habitat data of the Norman Wells Pipeline plant collections may be found in APPENDIX 2. In the list which follows the Kilometer Post (KP) is followed by the collection number.

POACEAE (GRAMINEAE) Grass Family

Agrostis scabra Willd., Rough Hair Grass — **0.3:** 85-55a; **150:** 84-59; **170:** 84-165; **192:** 85-72, 85-77; **287:** 89-53 **430:** 86-102; **527:** 85-94; **595:** 86-72; **636:** 89-21; **653:** 89-32.

This is a native species which frequently invades disturbed situations; in the Mackenzie River Valley known from as far north as Inuvik (Porsild and Cody 1980) where presumably introduced.

Agrostis stolonifera* L., Creeping Bent Grass — **287: 89-57.

This grass, has both native and introduced forms. It is widely distributed across Canada but has not previously been recorded as growing in the Continental Northwest Territories. Northern populations seem to be the result of introduction from further south (Dore and McNeill 1980), and could involve either native or introduced material.

Alopecurus aequalis Sobol., Water Foxtail — **430:** 86-106.

This is a native species widespread in the Continental Northwest Territories where it is found north to the limit of trees (Porsild and Cody 1980).

Alopecurus arundinaceus* Poir., Creeping Foxtail — **179: 84-175B; **192:** 85-66, 85-70b; **224:** 85-147; **287:** 89-59A; **306:** 86-124; **391:** 84-184; **527:** 85-106; **544:** 86-35b; **576:** 85-124; **579:** 86-46a, 86-46b; **595:** 86-65; **603:** 89-15; **628:** 86-52; **653:** 86-25; **678:** 89-41; **732:** 84-148.

This species, which was part of the seed mix applied in 1984, has not previously been recorded as growing in the Continental Northwest Territories. It

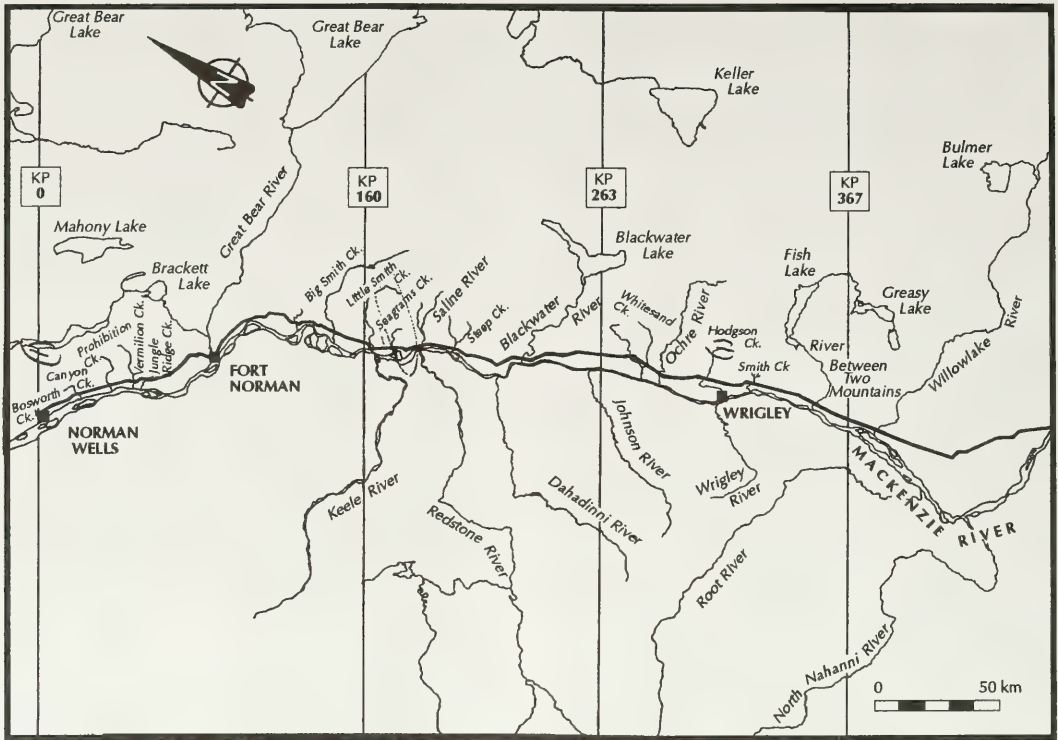


FIGURE 1a. Norman Wells Pipeline, northern part. KP = Kilometer Post

is a species native of Eurasia and apparently a recent introduction. It is being widely promoted in western North America as a forage. It differs from *A. pratensis* L. in having acute glumes with divergent tips, lemmas obliquely truncate or tapering abruptly, and lemma awns rarely or only slightly exerted from the spikelets. In *A. pratensis* the glume tips are parallel or convergent, the lemmas are acute and gradually tapering and the lemma awns are long and distinctly exerted from the spikelets.

Alopecurus pratensis L., Meadow Foxtail — **002**: 84-2A; **0.3**: 85-43; **18**: 86-130; **42**: 84-16; **65**: 84-35, 85-130; **240**: 85-80a; **391**: 84-183; **430**: 86-111; **529**: 85-110; **544**: 85-117.

This species has not previously been reported as growing in the Continental Northwest Territories. It is a species native of Eurasia that has been introduced widely across Canada and southward as a forage crop but has not done well for this purpose except on the Atlantic and Pacific coasts (Dore and McNeill 1980).

Avena fatua L., Wild Oats — **224**: 85-149a; **287**: 89-54.

Porsild and Cody (1980) reported this introduced species as an occasional weed in waste places in the Continental Northwest Territories.

Avena sativa L., Oats — **224**: 85-149.

Porsild and Cody (1980) reported this introduced widely cultivated species, as invading waste places in the Continental Northwest Territories.

Bromus commutatus Schrader, Hairy Chess — **240**: 85-141.

This is an annual weed of waste land which is introduced from Europe. To the south in Alberta it is rare along roadsides and in waste ground (Packer 1983). It has not previously been reported as occurring in the Continental Northwest Territories.

Bromus hordeaceus L. (*B. mollis* L.), Soft Chess — **65**: 84-34; **527**: 85-105; **529**: 85-111.

This species, which is naturalized from Eurasia, is found in Canada from the Maritime Provinces westward to southwestern Ontario and west of the Rocky Mountains through British Columbia to southern Alaska along roadsides, in old fields and in waste places (Pavlick 1995). It has not previously been reported from the Continental Northwest Territories.

Bromus squarrosus L., Corn Brome — **65**: 84-37B.

This introduced Eurasian species is known from southeastern British Columbia and eastern Washington to southern Manitoba and Kansas and

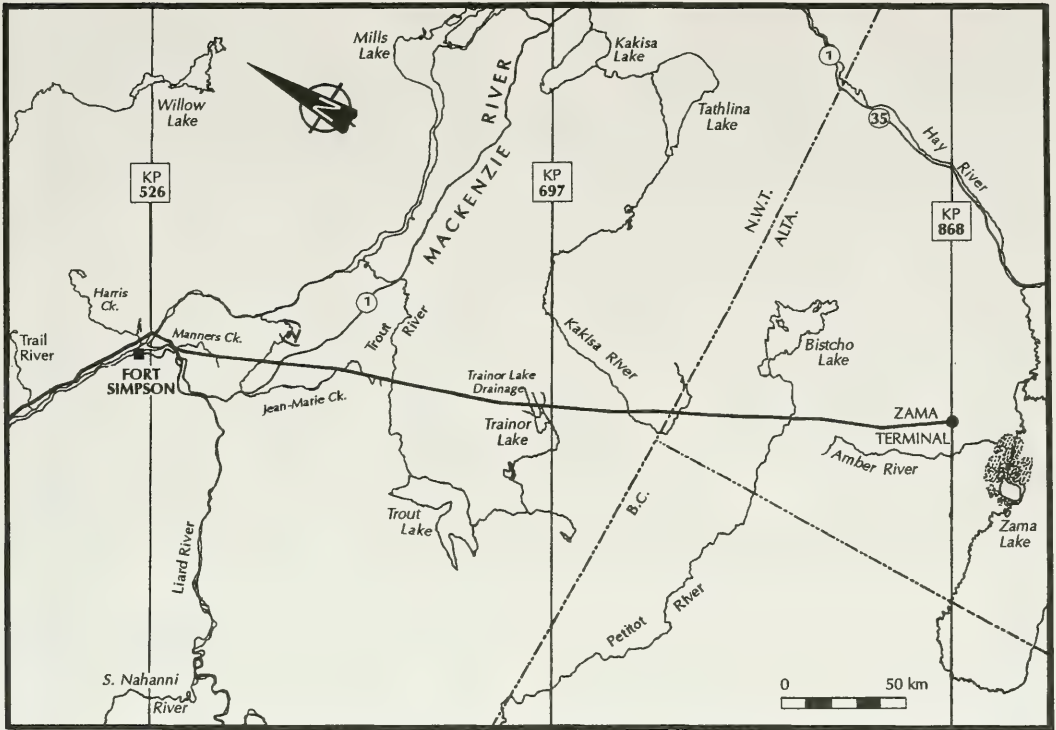


FIGURE 1b. Norman Wells Pipeline, southern part. KP = Kilometer Post

sporadically in southern Ontario and the New England States (Paylick 1995). It is new to the Continental Northwest Territories.

Bromus tectorum L., Cheatgrass, Downy Chess, Downy Brome — **0.02:** 84–6; **19:** 86–138; **48:** 84–28; **65:** 84–37A; **170:** 84–168; **192:** 85–65; **240:** 85–78, 85–143; **287:** 89–50; **527:** 85–101; **557:** 85–19, 85–164; **732:** 84–149.

This species, which is introduced from Europe, is now found in disturbed situations throughout much of the United States and southern Canada. The invasion of this species into western North America was documented by Mack (1981). It is the only grass noted by Johnson (1981) in his survey of construction sites on the Trans-Alaska Pipeline. The map in Upadhyaya et al. (1986) gives the first record of this species occurring in the Continental Northwest Territories: Mackenzie River below Norman Wells (65° 40'N 128° 50'W, W. Friesen 228, 23 Sept. 1972, (SASK)). The Great Slave Lake locality indicated was however an unfortunate error in mapping (R. Turkington, personal communication 1991).

Elymus trachycaulus (Link) Gould ex Shinnars s.l. (*Agropyron trachycaulum* (Link) Malte s.l.), Slender Wheat Grass — **0.05:** 84–1A (DAOM); **0.3:** 85–39; **19:** 85–58; **170:** 84–162 (DAOM);

179: 84–176 (DAOM); **192:** 85–68; **224:** 85–150; **240:** 85–81; 85–142; **270:** 85–86; **287:** 89–49, 89–51, 89–58; **305:** 89–48; **306:** 85–144, 86–122; **380:** 86–91; **391:** 84–189 (DAOM) **403:** 85–33; **430:** 86–109; **477:** 85–3, 85–4; **527:** 85–95A, 85–107B; **529:** 84–12, 85–113, 87–3, 89–47; **544:** 85–13, 85–116, 85–118, 86–33, 87–1; 89–46; **557:** 85–166; **576:** 85–126; **579:** 86–45, 87–10, 89–2, 89–3; **595:** 86–76, 87–11, 89–9; **628:** 86–57, 86–58, 89–20; **653:** 89–37, 89–38; **678:** 89–43; **732:** 84–142 (DAOM).

This species formed 28% of the seed mix applied in 1984 and increased to 43% in 1985. Usually it was also a major component in remedial seeding work for the period up to 1996. It is a native species occurring throughout most of Canada northward to Alaska. Porsild and Cody (1980) reported it in the Mackenzie River drainage north to the Delta. After the initial finding of head smut (*Ustilago bullata* Berk.) on this species in the pipeline right-of-way in 1984, there was increased collection and documentation of the presence of diseased populations (see Cody and MacInnes 2000) in subsequent years. The disease was not new to the Northwest Territories but had only been rarely collected on *Hordeum jubatum* and *×Elyhordeum macounii* (Vasey) Barkworth & Dewey (*Elymus trachycaulus* (Link) Gould ex

Shinners x *Hordeum jubatum* L.) (specimens at DAO and DAOM).

Festuca rubra L. s.l., Creeping Red Fescue — **0.3:** 85-40; **95:** 86-114; **430:** 86-105, 86-113; **477:** 85-5a, 85-5b; **527:** 85-97; **529:** 87-2; **544:** 86-36; **579:** 86-49, 87-9; **595:** 86-66, 86-75, 86-76a, 86-78; 87-13A; **603:** 89-12; **628:** 86-53, 86-56, 89-18; **636:** 89-23; **653:** 86-26, 86-28; **678:** 89-44.

This grass was included in the seed mix which was spread along the pipeline. The specimens cited above may have resulted from this seeding or have arisen from plants already in the region (Aiken and Darbyshire 1990; Porsild and Cody 1980).

Festuca trachyphylla* (Hackel) Krajina, Hard Fescue — **0.3: 85-41; **18:** 86-5, 86-131; **430:** 86-104; **527:** 85-98.

This species which is native to Eurasia is now introduced and naturalized in southern Canada from Nova Scotia to British Columbia (Aiken & Darbyshire 1980) and was also collected at Dawson, Yukon Territory in 1949 (Calder & Billard 3547 (DAO)). New to the flora of the Continental Northwest Territories.

Festuca valesiaca* Schleicher ex Gaudin ssp. *sulcata* (Hackel) Schinz & R. Keller (*F. rupicola* Heuffel) — **595: 86-70.

This Eurasian grass has been sporadically introduced at scattered locations in North America. It has not been previously reported from the Continental Northwest Territories.

Hordeum jubatum L., Squirrel-tail Grass — **0.02:** 84-5; **65:** 84-159; **170:** 84-167; **391:** 84-188; **527:** 85-103; **557:** 85-556; **576:** 85-121; **579:** 87-8, 89-4; **653:** 89-34; **678:** 89-42; **732:** 84-146.

Porsild and Cody (1980) reported this species, which is native to North America and eastern Asia, as "Often a troublesome weed common in waste places near townsites north to the Mackenzie Delta".

Lolium perenne* L. ssp. *perenne*, Perennial Rye Grass — **0.02: 84-1C; **65:** 85-131; **192:** 85-74; **391:** 84-107.

This subspecies has not previously been recorded as occurring in the Continental Northwest Territories, however an earlier specimen was collected by the airstrip at Fisherman Lake, 60° 20' N 123° 48' W in 1973 (Sheila M. Lamont FL339 (photo DAO)). A native of Europe, *Lolium perenne* is frequently included in seed mixes for revegetation because of its rapid germination and growth.

Lolium perenne* L. ssp. *multiflorum* (Lam.) Husnot (*L. multiflorum* Lam.), Italian Rye Grass — **0.02: 84-1B; **48:** 84-25; **65:** 84-33; **192:** 85-75; **240:** 85-84; **270:** 85-91; **287:** 89-52, 89-56; **391:**

84-106; **527:** 85-100, 85-102; **557:** 85-165; **732:** 84-143.

This subspecies has not previously been recorded as occurring in the Continental Northwest Territories, however a specimen was collected at the Columbia Gas Plant, Site E-37, 66° 06' 27" N 124° 07' 16" W in 1980 (D. W. Smith 18 (DAO)) and more recently at Yellowknife (roadside weed, seen in several places in town, M. H. Hils & J. W. Thieret, 19 July 1994 (DAO)).

Phalaris arundinacea L., Reed Canary Grass — **0.02:** 84-4; **170:** 84-169; **240:** 85-80; **391:** 84-185; **430:** 86-112; **477:** 85-7; **527:** 85-107; **579:** 89-7; **597:** 89-10; **603:** 89-13, 89-16; **628:** 86-55; **636:** 89-22; **653:** 89-31; **732:** 84-144, 84-147.

This species has both native and introduced genotypes in North America (Dore and McNeill 1980). In the Continental Northwest Territories it was previously known from south of Fort Simpson where presumably it was native. It was part of the seed mix which was applied in 1984.

Phleum pratense L., Timothy — **0.02:** 84-2B; **0.3:** 85-42; **48:** 84-27; **65:** 84-36; **150:** 84-57; **170:** 84-166; **179:** 84-175A; **192:** 85-70a; **240:** 85-83; **270:** 85-89, 85-92; **287:** 89-55, 89-59; **391:** 84-110; **430:** 86-103; **477:** 85-1; **527:** 85-104; **529:** 85-109; **544:** 85-9, 85-116a, 86-33; **557:** 85-18, 85-162; **576:** 85-123; **579:** 89-5, 89-6; **595:** 86-71, 89-11; **603:** 89-14; **628:** 86-50, 89-19; **632:** 85-30, 85-31; **653:** 89-35, 89-36.

This species was previously known as an introduction from Eurasia about settlements in southwestern District of Mackenzie as far north as Fort Simpson on the Mackenzie River (Cody 1961). It was part of the seed mix which was applied in 1984.

Poa annua* L., Annual Blue Grass — **527: 85-99; **732:** 84-145.

This introduced weedy species which is new to the Continental Northwest Territories is expected to be found in the future around settlements in the Territory (Porsild and Cody 1980).

Poa pratensis L., Kentucky Blue Grass — **192:** 85-67b, 85-73.

This species, which was part of the seed mix applied in 1984, was known to Porsild and Cody (1980) in the District of Mackenzie north to Norman Wells where it was mainly restricted to settlements and roadsides and considered probably not indigenous. It is often confused with and difficult to separate from the mainly arctic *P. alpigena* (Fr.) Lindm. and there are both native and introduced forms in North America.

Puccinellia borealis Swallen — **192:** 85-71; **240:** 85-82; **576:** 85-125.

Porsild and Cody (1980) considered this native,

non-littoral species of weedy habit as being readily spread by man and animals.

Secale cereale* L., Rye — **0.02: 84–3; **170**: 84–161; **477**: 85–2; **544**: 85–10, 85–114, 86–34.

Rye, which originated in Eurasia, is also planted in southern Canada for revegetation. It has not previously been found in the Continental Northwest Territories.

Triticum aestivum* L. (*T. hybernum* auct.), Wheat — **224: 85–148.

Wheat is a widely cultivated introduction from Eurasia. It occasionally escapes along roadsides and in waste places. It has not previously been found in the Continental Northwest Territories, but has been collected in the Yukon Territory (Cody 1996).

Vulpia bromoides* (L.) S.F. Gray, Barren Fescue — **170: 84–163.

Introduced from Europe, this is a common weedy species on the Queen Charlotte Islands, the Gulf Islands, on southern Vancouver Island and is infrequent along the mainland coast of British Columbia (Douglas et al. 1994). It extends southward to Chile and is rare inland in the United States. It has not previously been recorded from Continental Northwest Territories.

JUNCACEAE Rush Family

Juncus bufonius L., Toad-rush — **150**: 84–71; **192**: 85–63.

This is a cosmopolitan, non-arctic, weedy species which has previously been recorded only from damp roadsides in and near settlements of the District of Mackenzie, north to the Mackenzie Delta (Porsild and Cody 1980).

POLYGONACEAE Buckwheat Family

Polygonum arenastrum Jord. ex Bor., Oval-leaved Knotweed — **26.5**: 84–155; **65**: 84–44; **579**: 86–40.

Introduced from Eurasia. Much of what Porsild and Cody (1980) mapped as *P. aviculare* L. in townsites north to the Mackenzie River Delta should be referred to as *P. arenastrum* (McNeill 1981).

CHENOPODIACEAE Goosefoot Family

Chenopodium album L., Lamb'-quarters — **65**: 84–38, 85–136a, 85–137; **557**: 85–159.

Introduced from Eurasia and reported by Porsild and Cody (1980) from as far north as the Mackenzie River Delta.

Chenopodium berlandieri Moq. ssp. *zschackei* (Murr.) Zobel, Net-seeded Lamb'-quarters — **0.02**: 84–7; **26.5**: 84–157B.

Possibly introduced at these localities. In western District of Mackenzie it is known as a native from a number of disturbed situations as far north as latitude 67° 22'N (Porsild and Cody 1980).

Chenopodium capitatum (L.) Aschers., Strawberry Blite — **65**: 85–133; **192**: 85–60; **529**: 85–108; **557**: 85–17, 85–158.

This circumboreal species may be either indigenous or introduced at these localities. The map in Porsild and Cody (1980) indicates collections from about Great Slave Lake and as far north as the Mackenzie River Delta.

Chenopodium simplex (Torr.) Raf. (*C. gigantospermum* Aellen), Maple-leaved Goosefoot — **65**: 84–39; **632**: 85–28.

Thieret (1961) reported this species under *C. hybridum* L. var. *gigantospermum* (Aellen) Rouleau from Mile 60 Enterprise-Mackenzie River highway. The specimens cited above represent new localities. Although a native North American species it has been introduced into the Continental Northwest Territories.

Corispermum orientale* Lam. var. *emarginatum* (Rydb.) Macbr., Villose Bugseed — **26.5: 84–156; **65**: 84–43; **192**: 85–61.

This weedy plant is a new introduction to the Continental Northwest Territories. It may be separated from *C. hyssopifolium* L., (native to North America but adventive in the District of Mackenzie) by the essentially wingless (rather than definitely winged) fruit which measures 2.5 to 3.0 mm (rather than 3.5 to 4.5 mm in length). The genus *Corispermum* is taxonomically complex and this specimen will be reexamined following the completion of monographic work currently underway (Mosyakin 1995).

BRASSICACEAE (CRUCIFERAE) Mustard Family

Brassica rapa L. (*B. campestris* L.), Bird Rape — **224**: 85–151; **557**: 85–15.

Porsild and Cody (1980) reported this widely introduced Eurasian species only from Yellowknife.

Capsella bursa-pastoris (L.) Medic., Shepherd's Purse — **65**: 85–132; **179**: 84–177; **632**: 85–29.

This widespread introduced Eurasian species is known from numerous disturbed situations as well as along roadsides and in townsites in the District of Mackenzie as far north as Inuvik.

Descurainia sophia (L.) Webb, Flixweed — **0.02**: 84–10; **26.5**: 84–157A; **42**: 84–22; **65**: 84–41; **557**: 85–157.

Porsild and Cody (1980) reported this species, which is introduced from Europe, as common in the southern parts of the Mackenzie Valley. A report from Norman Wells (Cody 1960) was based on a misidentification.

Lepidium bourgeauanum Thell., Bourgeau's Peppergrass — **557**: 85–154; **579**: 87–6.

Porsild and Cody (1980) reported that this prairie or grassland species was fairly common in the

upper Mackenzie Valley where it was thought to be native.

Thlaspi arvense L., Penny-cress — **0.02:** 84–14; **65:** 84–42, 85–138; **170:** 84–171; **224:** 85–152; **732:** 84–151.

This Eurasian species was described as an introduced weed by roadsides and in waste places by Porsild and Cody (1980). It was previously collected in the vicinity of Norman Wells (*Cody & Gutteridge* 1960, 27 July 1953 (DAO)).

ROSACEAE Rose Family

Potentilla norvegica L. s.l., Rough Cinquefoil — **65:** 85–139; **150:** 84–76; **224:** 86–17; **287:** 89–60; **595:** 86–60; **653:** 86–22, 89–25.

Porsild and Cody (1980) mapped this somewhat polymorphic circumpolar species which has both native and introduced forms northward in the Continental Northwest Territories to near the limit of trees. It is of weedy habit and readily invades areas of disturbed soil, clearings and burns.

FABACEAE (LEGUMINOSAE) Pea Family

Medicago sativa L., Alfalfa — **732:** 84–150.

This widely introduced species was reported by Porsild and Cody (1980) as occurring at Alexandra Falls on the Hay River and Fort Simpson in the District of Mackenzie. Wein et al. (1992) reported additional stations at Fort Smith and Lower Hay River.

Melilotus alba Desr., White Sweet Clover — **527:** 85–93; **529:** 86–30; **579:** 87–7, 89–8; **653:** 89–28.

Cody (1956, 1961) and Wein et al. (1992) reported this widely introduced Eurasian species from the southern District of Mackenzie at townsites north to Fort Simpson.

Melilotus officinalis (L.) Lam., Yellow Sweet Clover — **653:** 89–27.

Cody (1956, 1961) and Wein et al. (1992) reported this widely introduced Eurasian species from the southern District of Mackenzie north to Fort Simpson.

Trifolium hybridum L., Alsike Clover — **0.02:** 84–15; **65:** 85–136; **472:** 86–88.

Cody (1956, 1963) reported this widely introduced species from townsites in southern District of Mackenzie as far north as the Liard River.

BORAGINACEAE Borage Family

Lappula squarrosa (Retz.) Dumort. (*L. echinata* Gilib.), Bluebur — **579:** 86–39.

This introduced cosmopolitan weed was known to Porsild and Cody (1980) as occasional in the townsites of southwestern District of Mackenzie.

PLANTAGINACEAE Plantain Family

Plantago major L., Common Plantain — **65:** 84–160; **192:** 85–62.

Previously known in the Continental Northwest Territories as a roadside weed in settlements northward nearly to the Mackenzie River Delta (Porsild and Cody 1980).

ASTERACEAE (COMPOSITAE) Composite Family

Artemisia biennis Willd., Biennial Wormwood — **65:** 85–129.

Porsild and Cody (1980) knew this native and cosmopolitan weedy species in the District of Mackenzie where it was confined to waste places near human habitations along the Mackenzie River and its tributaries north to the Arctic Circle.

Crepis tectorum L., Narrow-leaved Hawk's-beard — **0.3:** 85–36; **65:** 85–134; **224:** 85–153; **306:** 86–119; **544:** 85–115; **557:** 85–16, 85–155; **576:** 85–119; **579:** 86–42.

Porsild and Cody (1980) knew this introduced cosmopolitan weedy species only from townsites and roadsides in the southwestern area of the Continental Northwest Territories.

Discussion

The foregoing includes 34 alien taxa of which 15 are new to the flora of the continental Northwest Territories. The mitigative measures taken did not prevent the invasion of alien nor were they necessarily expected to do so. It is to be noted that the purpose of the present work was not to evaluate mitigation or make recommendations, only to update floristic data. It is additionally important to note that the various alien taxa reported could have invaded the pipeline either by contaminated seed or by long distance dispersal using a number of vectors including vehicles used during pipeline construction as well as animals and wind.

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APPENDIX 1. Initial main broad-based seed mixes specifically developed and used by Interprovincial Pipe Line (NW) Ltd. for seeding the Norman Wells Pipeline right-of-way primarily in March of 1984 and 1985.¹

Scientific names used	Common Name (Cultivar)	Percent by weight		Seed Sources Used
		1984	1985	
<i>Agropyron trachycaulum</i> (now <i>Elymus trachycaulus</i>)	Slender wheat grass (Revenue, Common) <i>North American</i>	28%	43%	Canada (AB)
<i>Festuca rubra</i>	Creeping Red Fescue (Boreal) <i>North American</i>	20%	27%	Canada (AB, BC), Germany
<i>Festuca ovina</i>	Hard Fescue (Durar, Sheep)	15%	0%	Canada (AB), Germany
<i>Alopecurus arundinaceus</i>	Creeping Foxtail (Common, Garrison)	15%	15/0%	Canada(BC), USA (Idaho)
<i>Alopecurus pratensis</i>	Meadow Foxtail (Common, Garrison)	0%	0/15%	USA (Oregon, Idaho)
<i>Phalaris arundinacea</i>	Reed Canary Grass (Vantage) <i>North American</i>	12%	9%	Canada (BC)
<i>Phleum pratense</i>	Timothy (Climax)	5%	6%	Canada (AB)
<i>Poa pratensis</i>	Kentucky Blue Grass (Common)	5%	0%	USA (Washington)

¹Interprovincial Pipe Line (NW) Ltd. July 1985. Norman Wells to Zama Pipeline. Revegetation Activities. March-April 1984 and February-March 1985. Prepared by UMA.CANUCK. HARDY. Construction Services Manager. (Supplier: Dawson Seed Co. Ltd., West Vancouver, British Columbia.)

APPENDIX 2. Location, date and habitat data of Norman Wells Pipeline Plant Collections. KP = location along pipeline from north to south starting at Norman Wells. Terrain/soils as designated on terrain-typed pipeline alignment sheets.

KP	Location	Latitude/Longitude	Year
0.02	Norman Wells. Pump Station Hummocky silty clay lacustrine soils over bedrock. Black Spruce/Larch scrub. Elevation: 60 m. Ice-rich permafrost. Trees and shrubs cleared in 1983. Ditched January 1984. Seeded March 1984.	65°17'N, 126°53'W	1984, 1986
0.3	Norman Wells 300 m south of Pump Station. Hummocky silty clay lacustrine soils over bedrock. Black Spruce/Larch scrub. Elevation: 60 m. Ice-rich permafrost. Trees and shrubs cleared in 1983. Ditched January 1984. Seeded March 1984.	65°17'N, 126°52'W	1985
18	North of Canyon Creek Hummocky till soils. Black Spruce-Labrador Tea scrub. Elevation: 120 m. Non ice-rich permafrost. Additional trees and shrubs cleared in 1983, widening older clearing. Ditched January 1984. Seeded March 1984.	65°14'N, 126°31'W	1986
19	Canyon Creek Hummocky till soils. Mixed Black Spruce and White Spruce with Alder and Birch depending on aspect. Elevation: 90–120 m. Non ice-rich permafrost. Additional trees and shrubs cleared in 1983, widening older clearing. Ditched January 1984. Seeded March 1984.	65°14'N, 126°30'W	1985, 1986
26.5	North of Christina Creek Hummocky colluvium. Black Spruce, White Spruce, Labrador Tea scrub. Elevation: 120 m. Ice-rich permafrost. Trees and shrubs cleared in 1983. Ditched January 1984. Seeded March 1984.	65°13'N, 126°24'W	1985
42	Vermillion Creek North Hummocky silty clay lacustrine soils. Black Spruce/Larch scrub. Elevation: 120 m. Non ice-rich permafrost. Additional trees and shrubs cleared in 1983, widening older clearing. Ditched February 1984. Seeded March 1984.	65°06'N, 126°07'W	1984
48	North of Jungle Ridge Creek Hummocky silty clay lacustrine soils with organic veneer. Black Spruce and Larch scrub. Elevation: 120 m. Ice-rich permafrost. Trees/shrubs cleared in 1983. Ditched February 1984. Seeded March 1984 and reseeded following thaw-settlement and ditchline erosion 1985.	65°05'N, 126°02'W	1984
65	Norman Range 12 km north of Tulita (Fort Norman). North of Bear Rock. Hummocky till veneer over bedrock. Spruce/Birch scrub on former burn area., Elevation: 150 m. Low ice permafrost. Trees and shrubs cleared in 1983. Ditched February 1984. Seeded March 1984.	64°59'N, 125°44'W	1984, 1985
95	Northeast of Police Island Hummocky silty clay lacustrine plain. Black Spruce/Larch scrub. Elevation: 150 m. Ice-rich permafrost. Trees cleared in 1983. Ditched February 1984. Seeded March 1984.	64°55'N, 125°15'W	1984, 1986
150	East of Mio Lake Hummocky sandy silt lacustrine plain. Black Spruce/Larch scrub. Elevation: 150 m. Non ice-rich permafrost. Former CNT landline clearing widened for pipeline right-of way in 1983. Ditched and seeded March 1984.	64°31'N, 124°46'W	1984, 1985, 1986
170	South of Seagram Creek Hummocky silty sand lacustrine veneer over ground moraine. Black Spruce/Labrador Tea scrub. Elevation: 150 m. Non ice-rich permafrost. Trees cleared in 1983. Ditched and seeded March 1984.	64°22'N, 124°38'W	1984
179	North of Saline River Silty sand lacustrine veneer over ground moraine. Black Spruce/Labrador Tea scrub. Elevation: 135 m. Non ice-rich permafrost. Trees cleared in 1983. Ditched and seeded March 1984.	64°18'N, 124°29'W	1984
192	North of Steep Creek Hummocky silty clay lacustrine plain. Black Spruce/Larch scrub. Elevation: 150 m. Ice-rich permafrost. Trees cleared in 1984. Ditched January 1985. Seeded March 1985.	64°13'N, 124°23'W	1985
224	North of Blackwater River Hummocky silty colluvium of slope. Former burn-Spruce/Trembling Aspen/Alder forest. Elevation: 135 m. Ice-rich permafrost. Trees cleared 1984. Ditched January 1985. Seeded March 1985. Erosion and additional later seeding of non-woodchip insulated areas and west side-cut of slope.	63°47'N, 124°09'W	1985, 1986
240	South of Blackwater River Silty clay lacustrine plain. Spruce/Aspen forest. Elevation: 185 m. Ice-rich permafrost. Trees cleared 1984. Ditched January 1985. Seeded March 1985.	63°47'N, 123°57'W	1985
270	Southwest of Table Mountain 10 km west of Table Mt., 50 km N of Wrigley. Hummocky silty clay lacustrine plain with 20–40 cm organic veneer. Black Spruce/Larch scrub. Elevation: 245 m. Icy permafrost. Additional trees and shrubs cleared in 1984, widening former seismic line tree clearing and including recent helipad clearing. Ditched January 1985. Seeded March 1985.	63°36'N, 123°39'W	1984, 1985

(Continued)

APPENDIX 2. (Continued)

KP	Location	Latitude/Longitude	Year
287	South of Ochre River Sandy-gravel flood plain south of Ochre River. White Spruce forest. Elevation: 185 m. Trees cleared 1984. Ditched January 1985. Seeded March 1985. Eroded by major flood in July 1988. Pipe excavated, reburied and floodplain area reseeded February–March 1989.	63°27'N, 123°37'W	1989
305	North of Hodgson Creek Sandy-gravel flood plain north of Hodgson Creek. White Spruce forest. Elevation: 215 m. Trees cleared 1984. Ditched January and seeded March 1985. Floodplain eroded by major floods in 1986 and in July 1988. Protective gravel berm constructed in 1987. Pipe excavated, reburied and area reseeded February–March 1989.	63°18'N, 123°28'W	1989
306	Hodgson Valve Tower Area 2 km south of Hodgson Creek. South of plain flooded in 1986 and 1988. Hummocky silty clay lacustrine plain Black Spruce/Labrador Tea forest. Elevation: 230 m. Ice-rich permafrost. Trees cleared in 1984. Ditched February 1985. Seeded March 1985. Additional fill added to ditchline due to settlement and erosion and reseeded winter 1986.	63°18'N, 123°27'W	1985, 1986, 1989
353	River Between Two Mountains 1 km south of river. Well-drained till. Boreal mixedwood–Spruce, Birch, Alder, Aspen. Elevation: 150 m. Trees cleared in 1983. Ditched March 1984.	62°57'N, 123°12'W	1984
380	Willowlake River winter road North side of Willowlake River. Area of road crossing and construction camp. 500 m west of pipeline. Sandy alluvial terrace. Boreal mixed woods. Elevation: 150 m. Non ice-rich permafrost. Seeding history, if any, unknown.	62°43'N, 123°05'W	1986
391	South of Willowlake River 11 km south of Willowlake River. Organic veneer over ground moraine. Boreal–Spruce/Larch. Elevation: 150 m. Non ice-rich permafrost. Area of former tree clearing for CNT landline. Additional trees/shrubs cleared 1983. Ditched February 1994. Seeded March 1984.	62°42'N, 123°05'W	1984, 1986
403	Unnamed Creek area 8 km east of Mackenzie River (Berry Island). Hummocky till-ground moraine. Boreal forest–White Spruce. Variable ground conditions from permafrost (ice-rich) to non-permafrost. Elevation: 150 m. Trees cleared 1983. Ditched February 1984. Seeded March 1984.	62°30'N, 123°02'W	1985
430	West of Ebbutt Hills Thin organic veneer over ground moraine. Former forest fire area. Regrown boreal mixedwood: Trembling Aspen, Balsam Poplar, Alder, Willow, Spruce. Elevation: 150 m. Non ice-rich permafrost. Trees cleared 1983. Ditched February 1984. Seeded March 1984.	62°19'N, 122°43'W	1984, 1986
472	South of Trail River 6 km south of Trail River. Hummocky sandy silt lacustrine plain. Spruce forest. Elevation: 120 m. Non ice-rich permafrost. Trees cleared 1983. Ditched February 1984. Seeded March 1984.	62°05'N, 122°04'W	1984, 1986
477	South of Trail River 10 km south of Trail River. Sandy-eolian dune area. Jack Pine/Balsam Poplar forest. Elevation: 150 m. Non-permafrost site. Trees cleared 1983. Ditched February 1984. Seeded March 1984 (Seed mix included annual rye.)	62°05'N, 121°59'W	1985
527	North of Mackenzie River Area includes old winter seismic line (trees/shrubs cleared), the newer pipeline right-of-way and the temporary pipeline construction camp site. Hummocky till-ground moraine. Boreal mixedwood. Elevation: 120 m. Non ice-rich permafrost. Trees/shrubs cleared for pipeline and camp in 1983. Ditched January 1984. Seeded March 1984.	61°50'N, 121°10'W	1985
529	Mackenzie River south 500 m south of the south bank of the river, near manual value site. Sandy silt lacustrine plain. Boreal mixedwood forest, White Spruce, Aspen. Elevation: 150 m. Non-permafrost site. Trees cleared 1984. Ditched February 1985. Seeded March 1985.	61°49'N, 121°10'W	1985, 1987, 1989
544	Simpson Dunes 10 km southeast of the Liard Ferry crossing. Sandy eolian dune. Mature Jack Pine. Elevation: 185 m. Non-permafrost site. Trees cleared 1984. Ditched February 1985. Seeded March 1985 (included annual rye in seed mix)	61°38'N, 121°10'W	1985, 1986, 1987, 1989
557	Near Manners Creek Hummocky organic veneer over sandy silt lacustrine plain varying to peat plateau with collapse scars/fens/bogs. Mature White Spruce forest to boreal mixedwood to sedge fens and cattails. Elevation: 185 m. Thin permafrost with variable to high ice contents. Non-permafrost in peat plateau collapse scars. Trees cleared 1984. Ditched February 1985. Seeded March 1985.	61°36'N, 121°06'W	1985

(Continued)

APPENDIX 2. (Concluded)

KP	Location	Latitude/Longitude	Year
559	Manners Creek Organic terrain (fen, thick mat of floating vegetation to thick organic veneer with shrubs and scattered Black Spruce/Larch. Elevation: 150 m. Non-permafrost site (fen). Shrubs cleared in winter 1984 (after building up thick ice road). Ditched February 1985. Seeded March 1985.	61°36'N, 121°05'W	1989
576	South of Jean Marie Creek Hummocky silty clay lacustrine plain. Boreal mixedwoods. Elevation: 185 m. Ice-rich permafrost. Trees cleared 1984. Ditched January 1985. Seeded March 1985. Additional seeding on eroded area summer 1985.	61°25'N, 120°56'W	1985
579	North of Mackenzie Highway 6 km north of pipeline/highway crossing. Hummocky sandy silt lacustrine plain. Boreal forest-White Spruce, Aspen. Elevation: 215 m. Permafrost with variable ice contents. Trees cleared 1984. Ditched January 1985. Seeded March 1985. Additional backfill placed in ditchline due to settlement and erosion and area reseeded 1986.	61°23'N, 120°55'W	1985, 1986, 1987, 1989
585	Mackenzie Pump Station Adjacent to Highway. Ground moraine over bedrock. Jack Pine forest. Elevation: 215 m. Trees cleared 1983 and 1984. Non-permafrost site. Temporary camp site and permanent location of the Pump Station. Seeded March 1985.	61°22'N, 120°53'W	1984
595	South of Mackenzie Highway 10 km south of the Mackenzie Highway. Hummocky till ground moraine. Boreal mixedwoods. Elevation: 245 m. Non-permafrost site. Trees cleared 1984. Ditched January 1985. Seeded March 1985.	61°17'N, 120°56'W	1986, 1987, 1989
603	Jean Marie Creek North Organic terrain. Peat plateau with collapse scars. Black Spruce/Larch scrub. Ice-rich permafrost in raised peaty areas. Elevation: 270 m. Scrub cleared 1984. Ditched February 1985. Seeded March 1985.	61°15'N, 120°45'W	1989
628	North of Trout River 43 km south of Mackenzie Highway. Till-ground moraine. Boreal mixedwoods. Elevation: 315 m. Non-permafrost site. Trees cleared 1984. Ditched January 1985. Seeded March 1985.	61°01'N, 120°35'W	1986, 1989
632	Trout River south bank Till-ground moraine. Boreal mixedwoods. Elevation: 315 m. Non-permafrost site. Trees cleared 1984. Ditched January 1985. Seeded March 1985.	60°59'N, 120°34'W	1985
636	South of Trout River Organic terrain. Peat plateau with collapse scars. Black Spruce/Larch. Elevation: 415 m. Ice-rich permafrost in raised peat. Trees and shrubs cleared 1984. Ditched January 1985. Seeded March 1985.	60°58'N, 120°34'W	1989
653	Temporary Staging Site Tree cleared area adjacent to pipeline right-of-area. (Pipeline construction camp and summer equipment parking area in 1984. Some post-construction use as helicopter fuel cache or camp area.) Till-ground moraine. Boreal mixedwoods: Willow, Alder, Spruce. Elevation: 450 m. Non ice-rich permafrost site. Trees cleared 1983. Seeded March 1985.	60°48'N, 120°21'W	1986, 1989
678	IPL(NW)Peat Trial area Organic terrain. Peat plateau ("bog") with collapse scars. Black Spruce/Larch. Elevation: 600 m. Ice-rich permafrost. Trees and shrubs cleared 1983. Ditched March 1984. Organic terrain not originally seeded. Following erosion of loose peat in ditchline, remedial work to limit ditchline erosion included experimental seeding 1988.	60°35'N, 120°17'W	1989
732	Kakisa River bank South bank of the river at the pipeline crossing (cut slope). Till-moraine. Former forest fire burn area. Immature Jack Pine-mixedwood. Elevation: 450 m. Trees cleared 1983. Ditched February 1984. Seeded March 1984. Hand re-seeded in summer of 1984 following surface mud flow.	60°09'N, 119°52'W	1984

Head Smut, *Ustilago bullata* on Slender Wheat Grass, *Elymus trachycaulus*, Introduced along the Norman Wells Pipeline, District of Mackenzie, Northwest Territories

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Vegetation and related studies to evaluate environmental mitigation along the Norman Wells to Zama Pipeline, included observations on the invasion of Head Smut, *Ustilago bullata* on Slender Wheat Grass, *Elymus trachycaulus* (sensu lato) (= *Agropyron trachycaulum*), a major component of the initial post-construction seed mix used along the pipeline for erosion control. This Pipeline Project involved the largest and most extensive revegetation program to date in the boreal forest and the discontinuous zone of the Northwest Territories. Potential host grasses were uncommon in the adjacent boreal forest area in the Territories; however disease introduction or re-introduction remained a risk even where certified seed mix components from outside the Territories were thought to be uninfected.

Key Words: Head Smut, *Ustilago bullata*, Slender Wheat Grass, *Elymus trachycaulus*, Norman Wells Pipeline, District of Mackenzie, Northwest Territories.

Cody et al. (2000) have described the pipeline revegetation program (using certified seeds) and government (Department of Indian and Northern Affairs) revegetation monitoring which followed the burying of the Norman Wells to Zama Pipeline, over a distance of 752 km, from Norman Wells, District of Mackenzie, Northwest Territories (latitude 65°17'N) to the Alberta border (latitude 60°N). Pipeline project revegetated areas were also monitored for weeds (aliens) and diseases and were found to contain 15 non-native taxa which were new to the flora of the Continental Northwest Territories, 19 alien taxa which were previously known in the Continental Northwest Territories but not adjacent to the pipeline, and 13 native North American taxa which were naturally uncommon in the pipeline area. Since all revegetation monitoring was incorporated into regular permafrost and terrain instrumented site monitoring and erosion monitoring by helicopter, the second author had an exceptional opportunity to make many observations (initially monthly, later focussed on the summer months) over the 752 km of pipeline in Northwest Territories for 12 years (1984 to 1996).

The first observation of a black fungus on grass inflorescences on the pipeline right-of-way was made in July 1984: collections were initiated and continued through 1989. The fungus was most common in the first and second summer following initial pipeline seeding (1984, 1985, 1986) and in areas of

erosion that had been subsequently re-seeded. The fungus might be visible between July and September and occurred on the major components of the initial seed mix used for pipeline revegetation. In total, in addition to the vascular plants, collections (Table 1) were also made of the fungus *Ustilago bullata* Berk. on *Elymus trachycaulus* (Link) Gould ex Shinners at 23 locations between Norman Wells and the Kakisa River, at Km 732, just north of the Alberta border. These collections, identified by D. B. O. Savile (1984) and J. A. Parmelee (1985–1989), are deposited in the National Mycological Herbarium (DAOM), Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Central Experimental Farm, Ottawa, Ontario. The fungus, *U. bullata* (Figure 1), causes a disease of grasses called Head Smut. The spores of *U. bullata* develop in the spikelets and usually destroy the ovaries and floral bracts. When mature, the spores are in dry, dusty, blackish-brown masses about the size of the grass seeds (Fischer 1953; Vanky 1994). Voucher specimens for the *Elymus trachycaulus* specimens are deposited in the Vascular Plant Herbarium (DAO) at the same locality.

Ustilago bullata has a worldwide distribution and it occurs on many species of Poaceae (Gramineae) (Vanky 1994). Canadian collections in the National Mycological Herbarium (DAOM) are hosted on the following genera: *Beckmannia*, *Bromus*, *Elymus*, *Agropyron*, *Hordeum*,

TABLE 1. Slender Wheatgrass, *Elymus trachycaulus*, specimens with Head Smut, *Ustilago bullata* collected by Kaye L. MacInnes along the Norman Wells Pipeline.

Pipeline KP	Coll. #	Date Collected	Location
0.05	84-1A	11 August 1984	Pump Station 1, Norman Wells
0.3	85-39	20 July 1985	Near Bosworth Creek, Norman Wells
19	85-58	9 August 1985	South side of Canyon Creek
170	84-162	19 September 1984	2 km south of Seagram Creek
179	84-176	22 September 1984	North of Saline River
224	85-150	6 September 1984	North side of Blackwater River
240	85-142	6 September 1985	South of Blackwater River
270	85-86	10 August 1985	West of Table Mt. South of river
287	89-49	10 August 1989	South of Ochre River (new seeding)
287	89-51	11 August 1989	South of Ochre River (new seeding)
305	89-48	10 August 1989	North of Hodgson Creek (new seeding)
306	85-144	6 September 1985	South of Hodgson Creek
306	86-122	17 July 1986	South of Hodgson Creek
391	84-189	22 September 1984	South of Willowlake River
477	85-4	17 July 1985	Sand dunes near Trail River
527	85-107B	12 August 1985	North side of Mackenzie River
529	84-12	17 July 1984	South side of Mackenzie River
529	85-133	12 August 1985	South side of Mackenzie River
529	87-3	9 July 1987	South side of Mackenzie River
529	89-47	10 August 1989	South side of Mackenzie River
544	85-118	12 August 1985	"Simpson Dunes" (Fall Rye trial area)
544	85-13	17 July 1985	"Simpson Dunes"
544	86-33	15 July 1986	"Simpson Dunes"
544	87-1	9 July 1987	"Simpson Dunes"
544	89-46	10 August 1989	"Simpson Dunes"
557	85-166	8 September 1985	Near Manners Creek
576	85-126	12 August 1985	North of Highway crossing
579	86-45	15 July 1986	North of Highway
579	87-10	9 July 1987	North of Mackenzie Highway
579	89-3	9 August 1989	North of Mackenzie Highway
597	86-76	14 July 1986	South of Highway
597	87-11	10 July 1987	South of Highway
597	89-9	9 August 1989	South of Highway
628	86-58	14 July 1986	North of Trout River
628	89-20	9 August 1989	North of Trout River
653	89-38	9 August 1989	Temporary staging site
732	84-142	12 August 1984	South bank of Kakisa River

Specimens in both Department of Agriculture DAO (Vascular Plants) and DAOM (Mycological) collections unless bold face for DAOM only.

×*Elyhordeum* and ×*Agroelymus*. Table 2 details the species and Canadian province localities represented in DAOM. In the United States it has also been reported on *Festuca* and *Sitanion* (Farr et al. 1989).

In the District of Mackenzie *Ustilago bullata* has been collected in the Mackenzie River Valley as far north as Fort Good Hope (66°15'N 128°38'W). All collections have been on *Hordeum jubatum* L. (Fort Providence, 61°22'N 117°38'W, *Cody & Matte* 8523, 4 July 1955; Rabbitskin River at Mackenzie River, 61°47'N 120°42'W, *Cody & Spicer* 11435, 1 July 1961; cabin clearing at mouth of Martin River about 8 mi downstream from Fort Simpson on the Mackenzie River, 61°56'N 121°35'W, *Cody & Matte* 8990; Fort Simpson,

61°52'N 121°22'W, *Cody & Matte* 8400, 28 June 1955; Fort Simpson, 61°52'N 121°22'W, *Cody & Matte* 8660, 7 July 1955; Fort Good Hope [66°15'N 128°38'W], *M. Newton s.n.*, 1 Sept. 1940) or on ×*Elyhordeum macounii* (Vasey) Barkworth & Dewey (cabin clearing on Mackenzie River, 8 mi downstream from Fort Simpson, 61°56'N 121°35'W, *Cody & Matte* 8991, 25 July 1955; rare in old field, Fort Simpson, 61°52'N 121°22'W, *Cody & Matte* 8659). None of these collections were found immediately adjacent to the Norman Wells Pipeline.

During the monitoring following the Norman Wells Pipeline construction, Head Smut was observed and collected only on *Elymus trachycaulus*, the major component of the pipeline seed

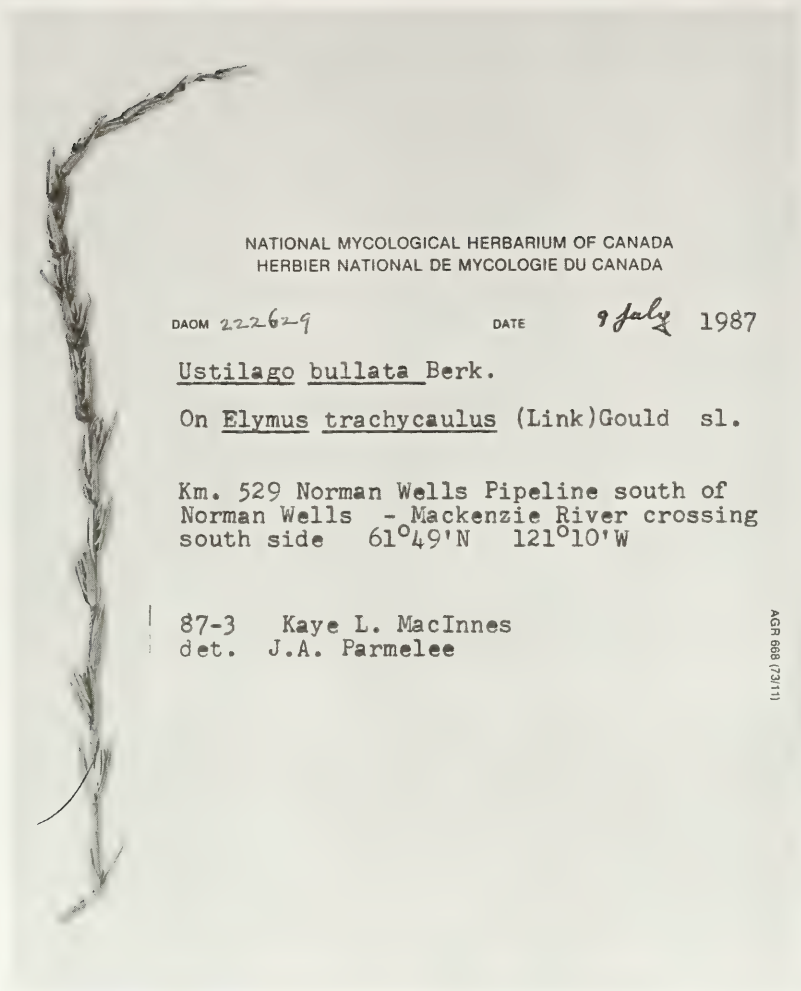


FIGURE 1. Head Smut, *Ustilago bullata* on *Elymus trachycaulus* senu lato.

mix. Head Smut was not observed on *E. trachycaulus* or on any other grass species in any of the relatively few areas adjacent to the pipeline where grasses occurred (usually disturbed areas) over the 1984-1996 period of observations.

Although it is possible that the Head Smut may have been introduced on equipment coming into the Territory for pipeline construction especially in 1984 and 1985, the Head Smut continued to appear at isolated sites where stocks of the initial seed mix were used for remedial work where seeds were flown to sites or taken by equipment now resident in the Territory. Virtually all access to the pipeline area is from a winter road only: most routine checks and patrols are done by helicopter. In our opinion, it seems most likely that the Head Smut collected during these studies was introduced to the pipeline area with the seed of Slender Wheat Grass. Areas

along the pipeline given remedial seeding between 1990 and 1996 showed no evidence of Head Smut. The presence of Head Smut would be of great concern if infected seed was dispersed along pipelines or other linear or non-linear project areas which pass through or are adjacent to grain fields or adjacent to protected ecological areas.

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TABLE 2. Hosts and localities outside of the District of Mackenzie of specimens harboring *Ustilago bullata* preserved in the National Mycological Herbarium (DAOM).

<i>Agropyron fibrosum</i> × <i>Elyhordeum macounii</i>	(= <i>Elymus trachycaulus</i> × <i>Hordeum jubatum</i>)	Manitoba Saskatchewan, Manitoba
<i>Beckmannia syzigachne</i>		Manitoba
<i>Bromus anomalus</i>		British Columbia
<i>Bromus biebersteinii</i>		Saskatchewan, Ontario
<i>Bromus carinatus</i>		British Columbia
<i>Bromus ciliatus</i>		British Columbia, Alberta
<i>Bromus hordaceus</i>		James Bay, Quebec, British Columbia
<i>Bromus mollis</i>		British Columbia
<i>Bromus</i> ? <i>racemosus</i>		British Columbia
<i>Bromus riparius</i>	(<i>B. biebersteinii</i>)	Saskatchewan, Ontario.
<i>Bromus schraderi</i>		Alberta
<i>Bromus sitchensis</i>		British Columbia
<i>Bromus sterilis</i>		British Columbia
<i>Bromus</i> ? <i>suksdorfii</i>		British Columbia
<i>Bromus tectorum</i>		British Columbia, Alberta Saskatchewan
<i>Elymus</i> ? <i>agropyroides</i>		Manitoba
<i>Elymus trachycaulus</i>	(<i>Agropyron trachycaulum</i> , <i>A. pauciflorum</i> , <i>A. richardsonii</i>)	British Columbia, Alberta Saskatchewan, Manitoba, Ontario, Quebec, Nova Scotia, Yukon, British Columbia, Alberta, Saskatchewan, Manitoba, Quebec
<i>Hordeum jubatum</i>		Saskatchewan, Quebec
<i>Hordeum laurentziana</i>		

Yellowknife provided excellent assistance in the collection of grass specimens.

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Notes

Field Anesthesia of American Mink, *Mustela vison*, Using Halothane

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Incidental to Muskrat (*Ondatra zibethicus*) capture-recapture operations in southcentral Saskatchewan, Canada, American Mink (*Mustela vison*) were captured and immobilized using halothane. Thirteen trials were performed on nine mink (7 M, 2 F). An initial dose of 4 mL provided complete anesthesia after 105 s (SD = 37 s, n = 7). Once anesthetized, stand-up posture and complete recovery occurred after a mean (SD) of 123 s (56 s) and 175 s (69 s), respectively. Multiple applications yielded longer and more variable induction times (311 ± 109 s), but similar stand-up (136 ± 80 s) and recovery times (182 ± 83 s). Halothane provided rapid (< 2 min) induction on calm mink, but all animals experienced traumatic anesthesia and recovery. One case involving multiple applications resulted in the death of one animal. We conclude that single applications of halothane may be used for anesthesia of American Mink for short (< 2 min) periods, but that the difficult recovery of immobilized Mink precludes the overall acceptability of this agent.

Key Words: American Mink, *Mustela vison*, anesthesia, halothane, immobilization.

Halothane gas is commonly used for the immobilization of Weasels (*Mustela erminea*; Murphy and Dowding 1994), Martens (*Martes americana*; Herman et al. 1982), and Striped Skunks (*Mephitis mephitis*; Larivière and Messier 1996). Its advantages include speed of induction and recovery, and ease in anesthesia procedures (Blanchette 1989). Because of its qualities as an anesthetic, it has gained popularity and is now widely used by researchers working on Muskrats, *Ondatra zibethicus* (e.g., Blanchette 1989; Marinelli and Messier 1993; Virgl and Messier 1996). In many areas of its distribution, the Muskrat is sympatric with the American Mink. Because both species are semi-aquatic, and are typically associated with permanent or semi-permanent bodies of water, researchers working on Muskrats often capture American Mink incidentally during live-trapping operations (e.g., Virgl and Messier 1996). Researchers capturing Mink incidentally may be tempted to use halothane, even though the safety of this agent on Mink has not been reported. Herein, we report on the use of halothane gas for the field anesthesia of American Mink.

From August to October 1994, American Mink were captured incidentally to an extensive Muskrat mark-recapture program conducted on Indi Marsh (51°41'N, 106°31'W) in southcentral Saskatchewan (Virgl and Messier 1996). Mesh-wire live traps (model 204, 18 × 18 × 51 cm, Tomahawk Live

Trap Co., Tomahawk, Wisconsin) were covered with vegetation, baited with carrots and checked daily. Mink captured accidentally were transferred to a transparent plexiglass box (16 × 16 × 34 cm) which provided a closed environment for anesthesia.

Halothane (4 mL) was poured directly under the door of the plexiglass handling box. Animals (all adults) were left undisturbed for 4 min, or until completely anesthetized (no reaction to toe pinching). Fully anesthetized mink were immediately removed from the plexiglass box for handling. Handling procedures were limited to eartagging, sexing, and weighing, and animals were observed until fully recovered. Recovery was monitored for two stages: 1) stand-up posture (typically accompanied with non-coordinated movements), and 2) complete recovery (unimpaired locomotion, gait normal). Recovery characteristics were calculated from the time animals were removed from the plexiglass box and hence no longer exposed to halothane.

Inadequately anesthetized mink were left in the plexiglass box. Failure to detect any sign of anesthesia 4 min after the initial application of halothane led to a second application. This time interval was based on our previous experience with Striped Skunks (Larivière and Messier 1996) and Muskrats (Virgl and Messier 1996). Volume of the second application depended on the state of the animal: fully awake animals received a full dose (4 mL) but partly anes-

TABLE 1. Halothane doses and times of induction, stand-up posture, and complete recovery for the anesthesia of American Mink in Saskatchewan, Canada.

Initial dose (mg)	Induction (sec)			Stand-up (sec)			Recovery (sec)		
	Mean	SD	n	Mean	SD	n	Mean	SD	n
Single dose trials ^a									
Males	116	38	5	147	48	5	202	62	5
Females	77	2	2	65	1	2	107	14	2
All Mink	105	37	7	123	56	7	175	69	7
Multiple dose trials ^b									
	311	109	6	136	80	5	182	83	5

^aSingle doses consisted of 4 mL of halothane. Induction was measured from time of application until complete anesthesia (no response to mechanical stimuli). Stand-up and recovery were calculated from time of induction until first stand-up posture and unimpaired locomotion, respectively.

^bMultiple dose trials involved 2-3 separate applications. Mean quantity of halothane applied was 7.3 ± 1.6 mL.

thetized animals received only a half-dose (2 mL). All procedures were performed at the capture site.

Thirteen trials were performed on seven males (mean body mass = 1.16 kg, SD = 0.16), and 2 females (mean body mass = 0.76 kg, SD = 0.10). Of these, 7, 4, and 2 trials involved use of a single, double, and triple application of halothane, respectively.

Single halothane applications ($n = 7$) provided complete anesthesia after 105 ± 37 s. Once anesthetized, American Mink exhibited stand-up behavior and complete recovery after 123 ± 56 s and 175 ± 69 s, respectively (Table 1).

Ease of recovery from halothane anesthesia could not be quantified, but was most often qualified as traumatic. When compared with anesthesia of Muskrats (Blanchette 1989; Virgl and Messier 1996) or Striped Skunks (Larivière and Messier 1996), halothane anesthesia of Mink was saltatory and difficult: anesthetized animals never experienced complete muscle relaxation, and breathing remained rapid and irregular throughout anesthesia. When recovering, animals often regained use of front limbs before hind limbs, and often dragged themselves in circles before recovering completely.

Multiple doses were applied in six cases, and resulted in longer induction times ($Z = -3.00$, $n_{\text{single dose}} = 7$, $n_{\text{multiple dose}} = 6$, $P < 0.01$), but similar stand-up ($Z = -0.08$, $n_{\text{single dose}} = 7$, $n_{\text{multiple dose}} = 5$, $P = 0.99$) and recovery times ($Z = -0.33$, $P = 0.76$) compared to single dose trials (Table 1). Furthermore, one male exposed to three applications (4 mL + 2 mL + 2 mL) became fully anesthetized after 472 s, but never recovered, and subsequently died < 2 min after reaching complete anesthesia.

American Mink have been anesthetized with numerous agents such as ketamine (Birks and Linn 1982), combinations of medetomidine-ketamine reversible with atipamezole (Arnemo and Sjøli 1992), ketamine-xylazine (Eagle et al. 1984), ketamine-midazolam (Wamberg et al. 1996), ketamine-acetylpromazine (Tomson 1987), ketamine-diazepam (Tomson 1987), and methoxy-

flurane (Tomson 1987). In this study, single applications of halothane provided rapid induction of calm Mink, but multiple doses led to the death of one male. Excited animals can develop life-threatening cardiac arrhythmias under halothane anesthesia (Sawyer 1982: 75), and excitement of mink captured in wire-traps was often high. Possibly, the use of opaque traps and opaque handling boxes could yield lower stress levels and safer anesthesia in American Mink, as was found for Striped Skunks (Larivière and Messier 1996). Also, the risk of overdose under open-drop application of halothane presumably increases with prolonged exposure. Maintenance of halothane anesthesia over periods exceeding ~5 min requires a small concentration of anesthetic ($\approx 1.5\%$; Sawyer 1982: 75) with the use of accurate and bulky delivery systems (Herman et al. 1982). Field conditions may not allow researchers to carry and use cumbersome equipment and complex procedures.

Although we immobilized only a small number of Mink, the difficult recovery of all Mink and the death of one animal resulting from multiple applications of halothane prevent us from recommending this agent at the present time. If it is used, procedures should be restricted to single applications and short (< 2 min) immobilization periods.

Acknowledgments

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Bull American Elk, *Cervus elaphus*, Mortality Resulting from Locked Antlers During Spring Sparring

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We documented two instances of antler-locked American Elk (*Cervus elaphus*) during spring sparring prior to antler shedding in the Black Hills, South Dakota. The first case occurred in Wind Cave National Park, where the locked elk were allowed to die naturally. The second case occurred on private land, where an attempt to free the locked elk resulted in the death of both bulls. Although instances of North American Elk and deer mortality due to antler locking have been documented during the breeding season, mortality due to spring sparring has not previously been reported in the literature.

Key Words: American Elk, *Cervus elaphus*, antlers, locked, management, scavenging.

Antlers are bony, secondary sexual characteristics commonly found in male cervids (McCorquodale et al. 1989). In American Elk (*Cervus elaphus*), antlers serve many functions and are utilized in establishing dominance, advertisement displays, displacement of conspecifics, and rutting activities. Bubenik (1973) stated that experienced bulls may be able to estimate social class and rank of conspecifics through observation of antler size and shape. Antlers are highly developed and represent potentially lethal weapons (Leslie and Jenkins 1985). Because of this potential danger, combat among male elk is highly ritualized to minimize injury (Bubenik 1973; Geist 1973; Leslie and Jenkins 1985), and prolonged periods of active fighting are relatively rare (Murie 1951).

Sparring between males is a technique used to maintain hierarchy within bull groups while avoiding

lethal injury. Sparring is not to be confused with fighting, as they are distinctly different phenomena (Murie 1951; Geist 1973). Geist (1973) stated that the use of antlers during sparring permits wrestling (which does not inflict pain) to signal the rank of the bull while maintaining gregariousness within the group.

Upsurges in sparring among elk are commonly observed during the rut and during the spring months of March and April, immediately preceding antler shedding (Murie 1951; Geist 1973; Prothero et al. 1979; Peek 1982). Hormonal changes taking place during the rut and during antler abscission could affect levels of aggression (Franklin and Lieb 1979), resulting in increased sparring. However, sparring also has been described as combat practice, a form of play, and as a means of maintaining dominance

(Murie 1951; Geist 1973; Franklin and Lieb 1979). Bulls that are comparable in age, size, and social rank are most likely to engage in sparring (Franklin and Lieb 1979; Geist 1973). Our observations in Wind Cave National Park were consistent with previous reports, as we often observed bull elk engaged in active sparring during the rut. We also observed playful sparring during early spring months. Spring sparring activity was greatest during early morning hours following fresh snowfalls.

True combat among bull elk during rut can result in fatal injury (Murie 1951; Leslie and Jenkins 1985). Murie (1951) reported that antlers may become interlocked in a slight sparring match, and locked antlers of young bulls that have perished have been found; likely a result of sparring during the rut. We found no reports of antler locking or deaths due to injuries sustained during spring sparring.

The following are two observational accounts of bull elk that became antler locked in the Black Hills, South Dakota. The antler-locked bulls in Wind Cave National Park were monitored daily from 15–25 February 1997. Monitoring sessions were usually conducted during crepuscular hours. These elk were allowed to die naturally under the National Park Service's Management Policies (National Park Service 1988).

On 15 February 1997 at 0800 h we observed two bull elk near a closed gravel road in Wind Cave National Park. The larger of the two had a small but typical six-point antler configuration. The smaller bull had a five-point antler configuration comparable in size to the six-point (Figure 1). The bulls had apparently bedded in a drainage near the road and were startled by our vehicles.

The bulls' antlers were locked together at nearly a 90 degree angle. The 5-point bull's forehead was

pressed against the lower mandible of the six-point bull, with his left antler locked to the right antler of the six-point bull. The six-point bull's fourth tine on the right antler was broken. The left brow tine of the five-point bull was pressed on the sagittal crest between the pedicles of the six-point bull. The right brow and bez tines of the six-point bull were lodged between the pedicles of the five-point bull. Each bulls' trez tine on the involved antler was crossed inside and around the trez and main beam of the opposing bull. This formed somewhat of an X shaped lock. The other antler on each bull was free of entanglement. Both elk had large patches of hair worn off of their shoulders and sides. The six-point bull had a long strip of hair rubbed off of his right side, starting at the shoulder and extending in a downward arch to his abdomen. Further observation showed that this hairless area was the result of the five-point bull repeatedly rearing up and dragging his left front hoof down the side of the six-point bull. The five-point bull's forehead was bleeding from the area where it was pressed into the six-point bull's jaw. This was the only visible trauma on either elk.

We observed the bulls for about 2.5 hrs, during which time they moved approximately 1 km from the initial observation area. At this point the bulls calmed considerably and stood resting, head to head, with little pushing. We received a report that the antler locked bulls were originally observed on 9 February 1997 in the same area. We returned periodically during the following days to observe the bulls from a distance.

By the end of the second day the bulls had moved approximately 50 m. The five-point bull appeared to be fatigued and both were emaciated around the hips. The five-point bull was found dead (10 days after the first reported observation) on the fifth day of observations. We observed the six-point bull drag the dead five-point bull approximately 15 m into the bottom of a nearby drainage, where the live bull remained standing.

Over the course of the next four days we periodically returned to observe the bulls. During most observations the live bull remained lying sternally recumbant and appeared to be severely malnourished and emaciated. We did not observe any foraging or drinking of free water, as water was not available in the immediate area. On day 7 the six-point bull stood and urinated profusely, which was surprising given that it had not drank for at least 7 days.

During the morning of the eighth day of monitoring we observed the six-point bull drag the dead five-point bull further down the drainage to a level area. The bull began struggling with the carcass. He twisted his head from side to side and pulled back with quick jerking motions. He then circled the carcass, effectively gaining a full twist on the head and neck of the dead bull. He held this position for some



FIGURE 1. Antler locked bull American Elk observed during spring in Wind Cave National Park. The bull on the left has a typical five-point antler configuration. The bull on the right is slightly larger and has a typical six-point antler configuration. Wind Cave National Park, South Dakota.

time, but the resistant pressure from the dead carcass apparently tired him and he released the tension.

On several occasions we observed predators and scavengers on and near the dead five-point bull, including Coyotes (*Canis latrans*), Golden Eagles (*Aquila chrysaetos*), American Crows (*Corvus brachyrhynchos*), and Black-billed Magpies (*Pica pica*). The rear flanks were the first to be scavenged. On 25 February 1997 at 0730 h the six-point bull was found dead (17 days after the first reported observation) and we investigated the carcasses. Both rear flanks of the five-point bull were nearly devoid of flesh, and the viscera had been scavenged. However, the rumen had been avoided. Neither bull showed evidence of fractured bones or other serious injury resulting from the fight. Field examination showed that femur bone marrow of both bulls was red and gelatinous, which suggested that the elk were nutritionally stressed (Bubenik 1973). We attributed poor bone marrow condition to the stress of the 17 days of struggle and starvation rather than typical winter stress, as most of the elk in the park appeared to be healthy and no winter mortalities due to starvation had been reported. Tooth aging, body size, and general appearance suggested the bulls were 2.5 to 3.5 years old.

On 7 February 1997 at approximately 0900 h, two bull elk also were found sparring on private land in the Black Hills, about 20.0 km from the location of the Wind Cave bulls (R. Halseth and T. Benson, South Dakota Department of Game, Fish, and Parks, personal communication). Barbed wire was entangled in the antlers and it was unclear whether the bulls were truly antler-locked. Personnel attempted to restrain the elk and remove the wire. The elk were approached and physically restrained within 5 minutes. Shortly thereafter the smaller bull lost consciousness and was assumed dead. Efforts were then concentrated on the larger bull, which also lost consciousness within minutes and died before the wire could be removed. The elk were assumed to have succumbed to myopathy (Pond and O'Gara 1994), presumably from being handled by humans in a stressful situation (Harper 1965; Bubenik 1973).

Postmortem examination indicated that the barbed wire was merely tangled in the antlers, and was not the cause of their being locked together. The right antler of the larger bull was deformed. This antler grew from a bony mass which was likely the deformed pedicle. The antler grew at a right angle, remaining sub-dermal for approximately 6 cm, then protruded through the skin near the side of the skull. The brow tine, also deformed, curved down over the ear and backwards, then extended proximally toward the head. This tine was roughly 38 cm in length. The rest of the antler beam was much shorter than normal and only carried three additional tines. The other bull was considerably smaller and carried a typical six-

point antler configuration. The deformed tine of the larger bull had hooked over the smaller bull's opposing antler, resulting in the locking of the antlers. The antlers could not be physically separated without cutting.

The lower incisors were collected and aged with tooth sectioning. The smaller bull was 4.5 years old and the larger bull was 5.5 years old. Both bulls appeared to be in excellent physical condition (L. Rice, South Dakota Department of Game, Fish, and Parks, personal communication).

The documentation of the death of four adult bulls in this relatively small geographic region is surprising given the lack of similar reports. Bull elk injury and mortality due to combat and antler locking during the rut are often reported and could potentially have a significant effect on numbers of mature bulls available for breeding in some North American elk populations. Our observations indicate that the impacts of injury and mortality due to spring sparring also could contribute to a reduction in mature bull elk. However, it is difficult to determine if spring sparring deaths could significantly impact the availability of mature bulls in a given population.

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Observations of Hooded Seals, *Cystophora cristata*, in the Northwestern Labrador Sea and Southern Davis Strait in March–April 1998

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Stirling, Ian, and Meike Holst. 2000. Observations of Hooded Seals, *Cystophora cristata*, in the northwestern Labrador Sea and southern Davis Strait in March–April 1998. *Canadian Field-Naturalist* 114(1): 147–149.

Observations of Hooded Seals were recorded along the ice edge from the northern Labrador Sea to Davis Strait between 30 March and 2 April 1998. A total of 131 seals were seen, including a dense group with breeding adults and pups on 1 April at 62°50'N, 57°20'W which appeared to be the southeastern edge of the Davis Strait whelping patch, the location of which has been recorded on only five previous occasions. From the ratio of lone pups to those still with their mothers, it appeared the peak of pupping had been up to about a week earlier.

Key Words: Hooded Seals, *Cystophora cristata*, breeding, pups, Labrador Sea, Davis Strait.

Hooded Seals (*Cystophora cristata*) are well known to congregate each year in March to pup in specific areas near Jan Mayen Island and in the north-west Atlantic near Newfoundland, with a subgroup in the Gulf of St. Lawrence (Øritsland 1959; Sergeant 1974). Sergeant (1974) reviewed anecdotal references to the existence of an additional whelping patch in Davis Strait and, in 1974, located it by aircraft and confirmed it was significant in size. In general, however, information on the distribution of Hooded Seals in the northern Labrador Sea and Davis Strait in early spring is limited and even the location of the whelping patch has been reported on only five previous occasions (Bowen et al. 1987). In 1984, Bowen et al. (1987) estimated the number of pups at 19 000 with a 95% confidence interval of 14 000 to 23 000, and estimated a peak pupping date of 24 March.

In this note, we report opportunistic sightings of Hooded Seals made along the floe edge in Davis Strait between 30 March and 2 April 1998, including the location of the southeastern edge of the Davis Strait whelping patch, made while en route from the

Gulf of St. Lawrence to the North Water Polynya on board the Canadian Coast Guard Cutter *Pierre Radisson*.

Methods

We observed seals using 10 × 50 binoculars from the bridge of the icebreaker, 15 m asl, between dawn and dusk (approximately 0800 to 1730) while the ship sailed along the southern edge of the pack ice. In general, the ice was more consolidated on the left side of the ship than the right as we traveled first generally north and then northeast. In areas where the floes were less consolidated, the ship traveled up to about a kilometer in from the edge of the ice specifically to facilitate additional sightings of seals. As our primary interest was distribution rather than density or estimation of abundance, all seals seen were counted, regardless of distance from the ship and, for each observation, we recorded the time, location, number, and species.

Hooded Seal pups are weaned at only 3–4 days of age (Bowen et al 1985; Lydersen et al. 1997) after

which the females mate right away (Boness et al. 1988; Kovacs 1990). Thus, whether pups were alone or with their mothers, and the presence of adult males consorting with lone females on the ice, or females that were still accompanied by their pups, provided evidence of the reproductive status of the animals seen and the timing of pupping. We also recorded sightings of Polar Bears (*Ursus maritimus*) and evidence of predation by them on the seals.

The distribution and percent cover of pack ice in the Labrador Sea and southern Davis Strait on 1 April were taken from the Davis Strait Ice Analysis map produced by the Canadian National Ice Center for the week 30 March – 3 April 1998.

Results and Discussion

Figure 1 illustrates the distribution and concentration of pack ice in the northern Labrador Sea and Davis Strait on 1 April and the ship's track during daylight hours. The locations where seals were sighted each day between 30 March and 2 April are plot-

ted. The ship's track at night was not recorded because no observations were made then.

On 30 March, we surveyed about 200 km along the ice edge and counted a total of 53 Hooded Seals hauled out on the ice, five in the water, and one Polar Bear. Most seals were lone non-breeding, or possibly post-breeding, animals widely scattered at intervals through the loose pack. One female was attended only by an adult male while a second was accompanied by both her pup and an adult male waiting to mate soon after the pup weaned. On 31 March, we surveyed approximately 155 km along the ice edge but saw only five lone Hooded Seals of unknown sex on the ice, one of which was a weaned pup, and two in the water. One Harp Seal (*Pagophilus groenlandicus*) of unknown age and sex was seen near the end of the day, which was the most northerly sighting we made of this species during our survey.

On 1 April we counted 72 Hooded Seals (66 on the ice and six in the water) over a distance of approximately 210 km, of which 27 were pups, and

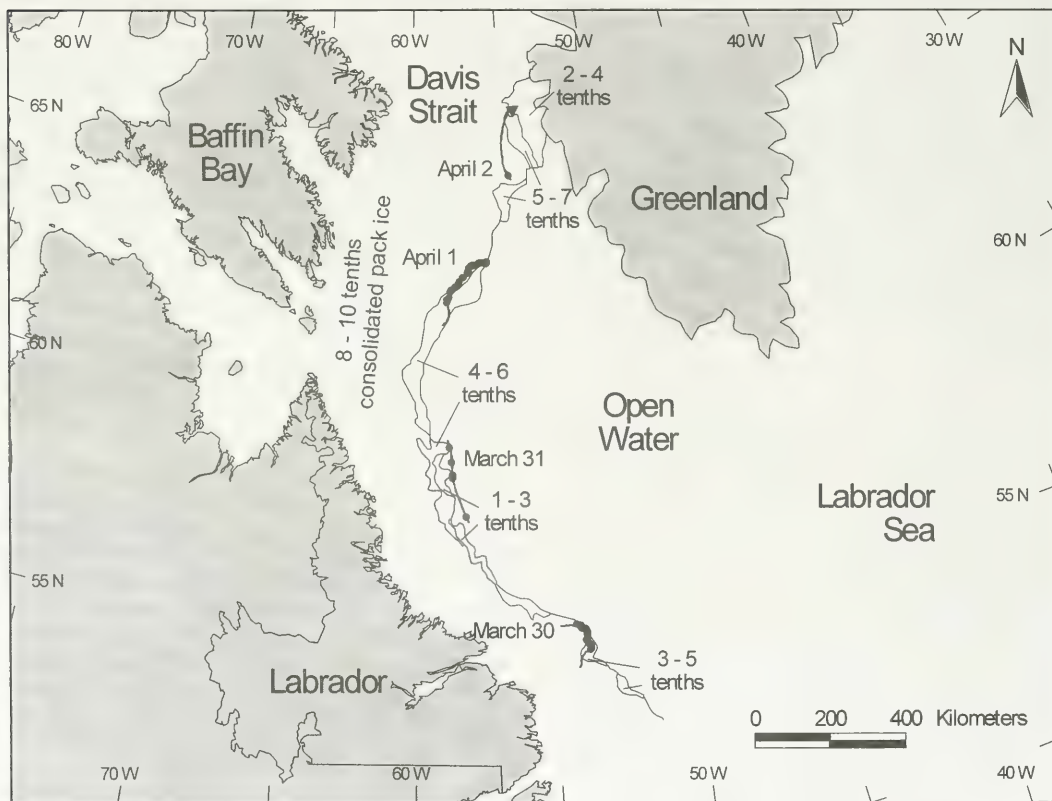


FIGURE 1. The distribution and concentration of pack ice in the northern Labrador Sea and Davis Strait on 30 March 1998. The track of the CCGC *Pierre Radisson*, during daylight hours is indicated by the darker line at the edge or parallel to the ice. The locations where seals were sighted from 30 March through 2 April 1998 are indicated by the • symbol. Gaps in the line between days indicates travel at night when no observations could be made. (The gaps are longer than the daily survey tracks because the nights are longer than the days at that time of year.)

three were still with their mothers. There may have been more young with females but if a pup was lying on the far side of a single seal observed some distance from the ship, it could not have been seen. Up until about 1600 h CST, most of the seals were individuals scattered along the edge of the ice similar to those seen on 30 March but, in a period of about 1.5 hours from 1600 to about 1730 h when it became too dark to identify animals reliably, we counted 39 seals, some only 100-200 m apart, nine of which were pups (three with their mothers), over a distance of roughly 35 km in loose floes. One adult female still with her pup was accompanied by an adult male, and four other males were observed spyhopping in the water near two females on floes with their pups as they searched for potential mates. We felt there were many more seals in this area (roughly centered on 62°50'N, 57°20'W) because we were still sighting animals regularly when pressure ridges on floes and fading light precluded further observations. In the area where Hooded Seals were most abundant, we also saw two adult female Polar Bears, each accompanied by one yearling cub, and a Hooded Seal female and her pup that had been killed and partially eaten by Polar Bears.

From our observations on the late afternoon of 1 April, we suspected that we passed along the southeastern edge of the general location of the Davis Strait Hooded Seal whelping patch. However, since it became too dark to see seals by 1730 h CST, we do not know how far along the floe edge the densest area for Hooded Seal adults and pups extended. On the following day, 2 April, we transited 180 km along the floe edge and saw only one Hooded Seal at the beginning of the day, the northernmost sighting of this species during our survey (64°55'N, 54°59'W), and one adult Polar Bear.

Since weaning in Hooded Seals takes place 4 days after birth, and only 11% (3/27) of the pups seen on 1 April were still with their mothers, it seems likely from Bowen et al. (1987, Figure 8) that the peak of pupping was up to about a week earlier. Also, since Hooded Seals normally pup on heavy floes in consolidated pack and the densest aggregations of animals we saw were in loose 5-7/10 pack, it seems possible the consolidated pack in the whelping patch had already broken up and drifted a bit to the south. Thus, we suspect the bulk of the whelping patch lay to the northwest of 62°50'N, 57°20'W where we

observed the greatest numbers of pupping and breeding Hooded Seals. This location is near where the whelping patches were in 1974, 1976, and 1984, but further east than in 1977 or 1978 (Bowen et al. 1987).

Acknowledgments

We particularly thank Captain Germain Tremblay and the officers and crew of the CGCC *Pierre Radisson* for taking a course along the edge of the pack ice, and into it whenever practical, so that we could survey seals while en route to the North Water. Their interest and support made these observations possible. We also thank the Natural Sciences and Engineering Research Council, the Canadian Wildlife Service, the Northern Science Training Program, and the Polar Continental Shelf Project for support, Nina Karnovsky and G. Hunt for their assistance with observing, and John Iacozza for producing the figure.

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News and Comment

Notices

Errata: *Canadian Field-Naturalist* 113(4)

Ricker, William E., and Jon T. Schnute. 1999. Westward trajectory extension for the earth-grazing fireballs seen on 9 February 1913. *The Canadian Field-Naturalist* 113(4): 693-697: on page 693, left column, line 5, and page 697, right column, line 1, the reference to "J. S. Plaskell" should be J. S. Plaskett, an editor's error. A brief biography of John Stanley Plaskett by A. H. Batten appears in *The Canadian Encyclopedia* Volume III: 1426 (1985 edition, Hurtig Publishers Limited, Edmonton, Alberta). My thanks to Allan Reddoch for bringing this to our attention.

Igl, L. D., D. H. Johnson, and H. A. Kantrud. 1999. Uncommon breeding birds in North Dakota: population estimates and frequencies of occurrence. *The Canadian Field-Naturalist* 113(4): 646-651. The last digit was inadvertently omitted from the confidence intervals for two species in Table 1. The population estimate (1000s of pairs) for the Ruddy Duck in 1993 should be 50 (0-93) rather than 50 (0-9), and the population estimate (1000s of pairs) for the Dickcissel in 1992 should be 74 (7-140) rather than 74 (7-14). The authors thank C. Stuart Houston for bringing these errors to their attention.

Recovery: An Endangered Species Newsletter (14)

The October 1999 issue, 8 pages, contains: Botanical gardens aiding plant recovery (David Galbraith); Commentary: The benefits of traditional knowledge (Deena Clayton); Essay: An evolutionary process - zoos find a new role in the conservation process (Brian Keating); COSEWIC Update: Peregrine Falcon on the rise (Chris Shank); Recovery celebrates ten years; Renew Update: A model conference - assessing population viability analysis; Nova Scotia law proclaimed [Nova Scotia Endangered Species Act]; ESRF [Endangered Species Recovery Fund] Update: Highest ever number of projects approved; Renew

Update; Recovery Watch: Web-based project links recovery teams [Sistrurus Information Network] (John Sorrett); Recovery Watch: Small, white and fragile - government and private agencies to monitor rare orchid (Elizabeth Punter); Featured Species: Sage Grouse continue to decline (Cameron L. Aldridge).

Recovery number 14 had a print run of 5000 English and 1000 French. It is available from the Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada or is accessible on the net at: <http://www.cws-scf.ec.gc.ca/es/recovery/archive.html>

Marine Turtle Newsletter (86)

Number 86, October 1999, 28 pages, contains: Guest Editorial: Operation Kachhapa: In Search of a Solution for the Olive Ridleys of Orissa: Articles: Current Status and Conservation of Marine Turtles on the Mediterranean Coast of Israel; Note: The Use of Goretex Mesh to Repair a Traumatic Coelomic Fistula in a Juvenile Green Sea Turtle; Letter to the Editors: On the Ostional Affair; OBITUARY: In Memoriam: Johan Paul Schultz (1921-1999); Meeting reports; Announcements; News & legal briefs, Recent publications.

The Marine Turtle Newsletter is edited by Brendan J.

Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, UK; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; Fax + 1 978 840 8184. MTN website is: <http://www.seaturtle.org/mtn/>

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF) (33 and 34)

Number 35, October 1999, contains: Changes in a Common Toad Population over 10 Years (Jan Clemons); Are Direct-Developing Frogs 'Immune' to the Amphibian Decline Syndrome? (Rohan Pethiyagoda and Kelum Manamendra-Arachchi); Call for Information on Urodeles and Caecilians (Tim Halliday); The Maya Forest Anuran Monitoring Project: A Cooperative Tri-National Effort (John R. Meyer); Frog Declines in New Zealand: Abstract (Ben D. Bell); Webfrog; Donations; Publications of Interest; Available from the DAPTF [bumper stickers, window stickers, sew-on patches].

Number 36, December 1999, contains: USGS [United States Geological Survey] New Release [Wildlife Health Alert: Chytrid fungus infection associated with deaths of

treated Boreal Toads in Colorado]; 10 September 1999 (Paul Slota); The Status of Some Amphibians of Bangladesh (Sohrab Uddin Sarker); Ecosystem Health Paradigm: Start Habitat Rehabilitations Now and Keep Doing Research on a Prioritized (Val Beasley);

Froglog is published bi-monthly and is edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Donations to support the work of the Declining Amphibians Populations Task Force can be made by cheque made out to "Smithsonian/Conservation and Science of Amphibians" sent to Ronald Heyer, Chair, DAPTF, NHB Mail Stop 180, Smithsonian Institution, Washington, D.C. 20560-0180.

Alberta Wildlife Status Reports (18 to 21)

The Fisheries and Wildlife Management Division of the Alberta Natural Resource Status and Assessment Branch, Alberta Environmental Protection, has released Wildlife Status Reports numbers 22 to 25. The Series Editor is Isabelle M. G. Michaud, the Senior Editor is David R. C. Prescott, and the illustrations are by Brian Huffman.

For a listing earlier numbers in the series, see *The Canadian Field-Naturalist* 112(1): 169 for 1-11; 113(2): 311 for 12-17; and 113(4): 686 for 18-21.

The newly published reports are:

22. Status of the Long-toed Salamander (*Ambystoma macrodactylum*) in Alberta, by Karen L. Graham and G. Lawrence Powell. 19 pages.
23. Status of the Black-throated Green Warbler (*Dendroica virens*) in Alberta, by Michael R. Norton. 24 pages.

24. Status of the Loggerhead Shrike (*Lanius ludovicianus*) in Alberta, by Kevin C. Hannah. 28 pages.

25. Status of the Western Blue Flag (*Iris missouriensis*) in Alberta, by Joyce Gould. 17 pages.

For copies: Information Centre - Publications, Alberta Environmental Protection, Natural Resources Service, Main Floor, Great West Life Building, 9920 - 108 Street, Edmonton, Alberta T5K 2M4, Canada (telephone: (780) 422-2079), or Information Service, Alberta Environmental Protection, #100, 3115 - 12 Street NE, Calgary, Alberta T2E 7J2, Canada (telephone: (403) 297-3362); or contact Isabelle M. Michaud, 7th Floor, O. S. Longman Building, 6909 - 116 Street, Edmonton, Alberta T6H 4P2; telephone (780) 427-1248; fax (780) 427-9685; e-mail Isabelle.Michaud@gov.ab.ca

New Brunswick Workshop on Animal Movement

The Workshop Proceedings *Investigation of Animal Movement* based on the sessions held 12-14 November 1998 at Fredericton, New Brunswick, has been edited by Falk Huettmann (Atlantic Cooperative Wildlife Ecology Network) and Jeff Bowman (New Brunswick Cooperative Fish and Wildlife Research Unit) and published as University of New Brunswick Ecology Publication Series Number 5, 84 pages, Sir James Dunn Wildlife Research Centre, University of New Brunswick, Fredericton, New Brunswick E3B 6E1. It contains - Introduction: investigating animal movement (Jeff Bowman and Falk Huettmann); Caribou movement as a correlated random walk [Abstract only] (Carita M. Bergman); Monitoring nocturnal bird migration with weather radar (John E. Black); An indirect approach to studying animal movement (Jeff Bowman, Graham Forbes, and Tim Dilworth); Using genetics to assess animal movement patterns (Hugh G. Borders); Winter movement of radio-tagged Atlantic salmon kelts in the Miramichi River in relation to ice [Abstract only] (R. A. Cunjak, S. M. Komadina-Douthwright, and D. Caisse); Relationship of weasel track tortuosity to prey abundance and vegetation structure (Mark A. Edwards, Jeff Bowman,

Graham Forbes, and Tim Dilworth); Effects of timber harvest on songbird breeding site-fidelity: an experimental approach [Abstract only] (Mitschka J. Hartley); Investigation of seabird movements: long-distance migration, stepping stones, age classes, modelling with Geographic Information System (GIS), and the seascape of the northwest Atlantic (Falk Huettmann); Distribution and conservation of the Leatherback Turtle (*Dermochelys coriacea*) in Atlantic Canada: research partnerships with the fishing community [Abstract only] (Michael C. James); Staging of Bonapart's Gulls in the Quoddy region of New Brunswick (Ken MacIntosh); Have all the froggies gone? Amphibian declines in the Atlantic region [Abstract only] (Donald F. McAlpine); A review and comparative analysis of three radiotelemetry technologies deployed on Woodland Caribou in Gros Morne National Park (Christopher McCarthy); Harmonic radar cannot yet be used to locate birds (Dorothy McFarlane); Animal movement paths and responses to spatial scale (Vilis O. Names); Radio-telemetry as a tool to investigate Arctic Tern (*Sterna paradisaea*) time-budgets [Abstract only] (Julie M. Paquet); Estimating movement with capture-mark-recap-

ture models (Gregory J. Robertson); Monitoring the movements of anadromous brook trout, using surgically implanted radio and acoustic transmitters (J. van de Sande, D. A. Courtemanche, R. A. Curry, and G. G. Whoriskey); Movements of haddock on eastern Georges Bank obtained from a population model incorporating temporal and spatial

detail (Lutgarde A. M. Van Eeckhaute, Stratis Gavaris, and Edward A. Trippel); Monitoring health, genetic diversity, movement, and fission-fusion social patterns in a New World monkey (*Alouatta palliata*); and interdisciplinary project (Linda A. Winkler, Greg Peter, Rex Sohn)

Canadian Amphibian and Reptile Conservation Network Réseau Canadien de Conservation des Amphibiens et des Reptiles

Abstracts of Conference held Quebec City, Quebec, 14-18 October 1999. Jacques Jutras, Coordinateur herpétofaune et micromammifères, Service de la Faune terrestre, Faune et Parcs, Gouvernement du Québec, 675, boulevard Rene-Levesque Est, 11e etage, boîte 92, Québec, Québec G1R 5V7, Canada.

Habitat characterization and selection within the home range of Wood Turtles (*Clemmys insculpta*): Martin Arvisais, Esther Levesque, and Jean-Claude Bourgeois; Association between sexually dimorphic traits, gonadal development, and behaviour of hatchling Snapping Turtles (*Chelydra serpentina*) with organochlorine exposure: Sara L. Ashpole, Shane R. de Solla, Christine A. Bishop, and Ronald J. Brooks; Genetic structure, phylogeography and gene flow in the Bullfrog (*Rana catesbeiana*): James Austin, Steve Lougheed, and Peter Boag; Children helping amphibians: Daniel Bergeron; Tunnels for amphibians: Daniel Bergeron; Important reptile areas and important amphibian areas of Canada - a case study of Pelee Island: Christine Bishop, Ben Porchuk, Robert Willson, and Jeremy Rouse; Contaminants and wildlife in 15 stormwater detention ponds in southern Ontario: Christine Bishop, John Struger, Lesley Dunn, Donna Bedard, and Leonard Shiroy; 1999 Baskathon - a first for the world: Christine Bishop, Matt Mills, Bruce Duncan, and Glenn Barrett; Securing keystone habitats: Joel Bonin; The old forests - shelter for salamanders: Joel Bonin, Jean-Francois Desroches, Martin Ouellet, and Alain Leduc; Wood Turtle (*Clemmys insculpta*) numbers in southern Ontario: Ronald J. Brooks, Shane R. de Solla, and Sarah M. Holt; Progress towards a national frogwatch program: Brian Craig; Evaluating four types of salamander cover boards at Smithsonian Institution Forest Biodiversity Permanent Plots utilizing student volunteers: Brian Craig, Christine Rikley, Brad Slade, Ashley Way, and Nick Wilson; Synergistic effects of the Xenoestrogen 4-Octylphenol (4-OP) and UV-B radiation on somatic development and gene expression in the forebrain of the Leopard Frog (*Rana pipiens*): Doug Crump, Vance L. Trudeau, and David Lean; Herpetology in Guam: David Cunningham; The anomaly P of Green Frogs *Rana* (*Pelophylax*) *synk. esculenta* and related anomalies in amphibians from Europe: Alain Dubois; Advance in a crowded country: methods for public education to promote herp conservation in Britain: Jim Foster and Jennifer Barr; A preliminary study of the incidence of deformities in Green Frogs (*Rana clamitans*) and Northern Leopard Frogs (*Rana pipiens*) on Prince Edward Island: Natacha Gallant, Kevin Teather, and Neil Burgess; Spatio-temporal use of northern Lake Champlain by the Spiny Softshell Turtle (*Apalone spinifer*): Patrick Galois; Amphibian abnormalities and heavily managed land uses in Vermont: Monique M. Gilbert, Wendy Houston-Anderson, and Kari Dolan; Levels of external developmental abnor-

mality and traumatic injury in Panamanian anuran populations: Heather M. Gray, Martin Ouellet, and David M. Green; COSEWIC - endangered species designation in Canada: David M. Green; Statistical estimation of amphibian malformation: Greg Heller; Will global warming cause the decline of species with temperature sex determination?: Sarah M. Holt and Ron J. Brooks; Public participation and outreach programming for the recovery of threatened species and their habitats: Bob Johnson; Abundance, mortality and age distribution of three species of ranids in Algonquin Provincial Park, Ontario - are amphibians declining in undisturbed habitat?: Kevin A. Judge, J. Cameron MacDonald, Sarah J. Swanson, and Ronald J. Brooks; Northern Painted Turtles (*Chrysemys picta*) - simultaneously abundant and rare: Amanda P. Karch and Ronald J. Brooks; Natural occurring morphological abnormalities in wild populations of *Ambystoma maculatum* and *Notophthalmus viridescens*: Patrick Labonte, Marie-Claude Carboneau, Martin Ouellet, and Jean Rodrigue; A major die-off of Red-sided Garter Snakes at Narcisse Wildlife Management Area, Manitoba in 1999: Ronald A. Larche and David Roberts; Ecodemography of a population of the Redback Salamander, *Plethodon cinereus*, from the Laurentian Shield: Marc Levasseur, Maria Helena Leclair, and Raymond Leclair; Testing competing vicariance hypotheses of Amazonian diversification using two species of frog: Stephen C. Lougheed, Claude Gascon, James P. Bogart, and Peter T. Boag; The effects of ground cover, soil moisture, and soil urine content on nest-site selection of Painted Turtles (*Chrysemys picta*) in Algonquin Park: Elaine Matthews and Ron Brooks; Amphibian activity, movement patterns and body size in fragmented peat bogs: Marc J. Mazerolle; Prevalence of morphological deformities and traumatic injuries in New Brunswick anurans - preliminary data: Donald F. McAlpine, Meagan A. Osepchuk, and Timothy J. Fletcher; The evolution of the breeding system of the Painted Turtle (*Chrysemys picta*): Seanna McTaggart and Ronald J. Brooks; Volunteers as integral participants of amphibian and reptile monitoring studies: Karyn Molines and Christopher Swath; Aspects of the migratory activity of Marbled Salamanders, *Ambystoma opacum*: Karyn Molines and Christopher Swath; Study of daily movements during nesting period and location of potential nesting sites for the Wood Turtle (*Clemmys insculpta*): Serge Montour, Martin Arvisais, and Jean-Claude Bourgeois; Science, societies, advocacy, and ethics: Henry R. Mushinsky and Earl McCoy; Contemporary attitudes towards amphibians and reptiles: Stan A. Orchard and Lynn O. Miers; Perspectives on herpetological education and its relation to conservation biology - introductory remarks: Stan A. Orchard; In the kingdom of the wetlands - an environmental education project: Diane Ostiguy; Ichthyophonosis - an enzootic disease in free-living

amphibians from Quebec: Martin Ouellet, Igor Milaelian, Bruce Pauli, Jean Rodrigue, and David M. Green; State of the Wood Turtle (*Clemmys insculpta*) population in the Maricic region: Sylvain Paradis, Jean-Claude Bourgeois, Claude Daigle, Jacques Jutras, and Denis Masse; Wood Turtle, *Clemmys insculpta*, injury and mortality in a Vermont, USA, population: Steven G. Parren; Sampling biases in demographic analyses of Black Rat Snakes (*Elaphe o. obsoleta*): Kent A. Prior, Gabriel Blouin-Demers, and Patrick J. Weatherhead; Strategic planning for herpetofaunal recovery in Canada: from past practices to future gains: K. Prior and S. Nadeau; The educational aspects of the international salamander year, a twelve country project in Europe: Miklos Purky, Katja Pobljsaj, Biljana Janev, Ana Paunovic, Gyongyver Mara, Peter Schad, Dorottya Gemesi, Agnes V.-Pongracz, Ferenc Tompa, and Judit B.-Balogi; 1999 - European Pond Terrapin year in Hungary: Miklos Puky, D. P. Gemesi, I. Ludmann, and R. B. Sallai; Mass occurrence of deformities in a *Bombina bombina* population in the Danube floodplain at Szeremle, Hungary: Miklos Puky; Educational activities relating to herpetofauna at the Ecomuseum, and their implication: David Rodrigue and J. Roger Bider;

Chlorinated hydrocarbon concentrations in plasma of the Northern Water Snake (*Nerodia sipedon*) from the Great Lakes Basin: Jermy D. Rouse and Christine A. Bishop; Multimedia technology as a tool in herpetological education: Andrea Sangster; Mudpuppy night in Oxford Mills - its your only chance to see an active amphibian when the air temperature is -26°C!: Frederick W. Schueler; Regional "Top 10" lists of herpetogaunal decline: Frederick W. Schueler; Application of metapopulation theory to practical conservation, with the pool frog *Rana lessonae* as a focal example: Per Sjogren-Guive; *In vivo* induced photolysis activity of Wood Frog (*Rana sylvatica*) embryos: Alex Smith, Carolyn Kapron, and Michael Berrill; Demography and home ranges of Wood Turtles, *Clemmys insculpta*, in Algonquin Park, Ontario: Kim Smith and Ronald J. Brooks; Geographic variation in the life history of the Painted Turtle, *Chrysemys picta*: Robert Van Vlaenderen and Ronald J. Brooks; Nesting ecology and hatching success of the Wood Turtle, *Clemmys insculpta*: Andrew D. Wade, Roger Bider, Denis Masse, and Rodger Titman; Ecology and conservation of Pelee Island's endangered snake fauna: Robert Willson, Ben Porchuk, Jeremy Rouse, and Ron Brooks.

New Book Distributor for *A Field Guide to the Life and Times of Roger Conant*

A Field Guide to the Life and Times of Roger Conant
By Roger Conant. 1997. Selva, Canyonlands Publishing Group, L.C. Provo, Utah. xix + 498 pp., illus., reviewed in *The Canadian Field-Naturalist* 113(3): 554-555, has a new distributor: Bibliomania, P. O. Box 58355, Sault Lake City, Utah 84158-0355, USA; Phone/Fax (801) 453-0489; e-

mail: breck@herplit.com; WWW site: <http://www.herplit.com>. US\$49.95, postage US\$2.50 within the United States, postage and shipping costs outside the United States available on request.

FRANCIS R. COOK

American Society of Mammalogists 80th Annual Meeting

The 80th Annual Meeting of the American Society of Mammalogists will be held 17-21 June 2000 at the University of New Hampshire, Durham, New Hampshire, USA. In addition to contributed oral and poster presentations covering all aspects of mammalian biology, this year's program features a symposium entitled "Movement as a link between behavioral and landscape ecology: mammals as models", chaired by Dr. Patrick Zollner. Also included are the usual ASM socials, ideal for professional interaction.

Non-members who are interested in attending the meetings and/or presenting papers should request materials from the Chairman of the local Program Committee, Dr. John Litvaitis, Department of Natural Resources, James Hall, University of New Hampshire, Durham, NH 03824; 603-862-2094; FAX: 603-862-4976; GOTOBUTTON BM_1_ e-mail: john@christa.unh.edu.

For additional information regarding conference arrangements contact Dorrie McClintock (UNH Conference Office; e-mail: dsm@hopper.unh.edu).

KERRY S. KILBURN

A Tribute to Henri Roger Ouellet, 1938–1999†

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McNeil, Raymond, and W. Earl Godfrey. 2000. A tribute to Henri Roger Ouellet, 1938–99. *Canadian Field-Naturalist* 114(1): 154–164.

Henri Roger Ouellet was born in Rivière-du-Loup, Québec, on 29 January 1938, to Charles Eugène Ouellet and Antonia Dubé. He passed away suddenly and unexpectedly on 9 January 1999 at his residence in Hull, Québec, at the age of 60. He is survived by his wife, Yvette Testuz, and a son, Alain.

His secondary education began at Externat Classique in Rivière-du-Loup. There, at the age of 13, his interest in taxidermy and the study of birds was encouraged by Rev. Rosaire Deschênes. Thereafter, both Henri (at the age of 16) and his friend Raymond McNeil were influenced while at the Collège de Ste-Anne in La Pocatière, Québec, by Rev. René Tanguay, who taught us how to prepare bird skins for the college museum, and thereby had an enormous impact on their subsequent careers. When Henri and McNeil applied to the National Museum for summer field employment in New Brunswick in 1957, their skills in the preparation of bird specimens, thanks to Rev. Tanguay, were the main reason the two of them were selected from a long list of applicants. Both of them had similar employment at Knob Lake and Schefferville in northern Québec in 1958. Thus began Henri's lifelong association with the National Museum of Canada.

Henri was also influenced by Dionne's *Les oiseaux de la Province de Québec* (1906) and Taverner's *Birds of Canada* (1934). In 1955, Henri's family moved to Québec City, where he continued his college studies at Académie de Québec, a college affiliated with Université Laval. He obtained a B. ès L. (French and History) degree in 1958. In September 1958, Henri enrolled in the Biology Department of the University of New Brunswick in Fredericton where he graduated in 1962 with a B. A.

in biology. During the summers of 1959 through 1961, he continued ornithological surveys for the National Museum of Canada. In 1962–1963, as a field assistant in ornithology, he surveyed the avifauna of Anticosti Island, resulting in the publication of *Les oiseaux de l'île d'Anticosti, Province de Québec* (Musées nationaux du Canada, Publication en zoologie no. 1, 1969). Next he translated Godfrey's *The Birds of Canada* from English into French. Following a short period as chief naturalist at the Point Pelee National Park, Ontario, he was, from 1965 to 1970, assistant, and then associate, curator at the Vertebrate Zoology section of the Redpath Museum, McGill University, Montréal. During those years he conducted summer ornithological surveys in the Monteregian Hills in southern Québec, the Gaspé Peninsula, and the Saguenay, Lac St-Jean, and Abitibi regions. While at the Redpath, he was enrolled in M.Sc. studies at the McGill Department of Zoology, graduating in 1967. His thesis, *Les oiseaux des collines montréalaises et de la région de Montréal, Québec, Canada* (Musée national des sciences naturelles, Publication en zoologie no. 5), was published in 1974. Under the supervision of A. W. Cameron and Peter R. Grant, he began his Ph.D. studies at McGill University in 1967, graduating in 1977 with a thesis on biosystematics and ecology of Hairy (*Picoides villosus*) and Downy (*P. pubescens*) woodpeckers.

While still working on his Ph.D. thesis, he was enrolled as assistant curator (1970–1976) of the ornithology section of the National Museum of Natural Sciences in Ottawa. In 1977 he succeeded his mentor, W. Earl Godfrey, as curator of birds and chief of the vertebrate zoology division of the museum until August 1991, when curatorships at the Canadian Museum of Nature were abolished. Most curators thus became research scientists in their area of specialty with only an "intellectual" advisory role regarding the national collections. In 1993, following another disastrous reorganization, most vertebrate zoology scientists at the Canadian Museum of Nature were fired. Henri continued as a volunteer researcher emeritus with access to collections, visiting the muse-

†The text portion of this tribute has also appeared *The Auk* 116(4): 1118–1121. [1999].

See also:

Ouellet, Réginald, et Michel Lepage. 2000. Décès d'un ornithologue de réputation internationale : le Dr Henri Ouellet — 1938–1999. *Le Naturaliste canadien* 124(1): 5–6.



Henri Roger Ouellet, 1938–1999. Photograph taken in June 1983, near La Grande, James Bay, Québec.

um collections and library irregularly until his death, but many of his projects remain unfinished.

Henri's main research and ornithological interests were in distribution, zoogeography, and systematics, but he also investigated ecology and behavior. Between 1970 and 1991, he was instrumental in enhancing the development and expansion of the national ornithological collections at the National Museum of Natural Sciences, through field collecting, exchanges, acceptance of gifts, and purchases. Indeed, from 1970 to 1985, he conducted and/or directed for the museum over 17 ornithological surveys in various parts of Canada, from Newfoundland and Labrador to the Yukon and Ellesmere Island, Northwest Territories. His special emphasis was on the Québec-Labrador Peninsula. He also conducted field investigations in the Lesser Antilles, French Guiana, Argentina, and Venezuela for studies on the systematics and evolution of selected neotropical Emberizine genera. Particular emphasis was placed on filling gaps in the geographic representation of Canadian material, acquiring specimens in particular groups poorly represented in the collections, and on broadening the global geographic representation of specimens, particularly from the Neotropics.

During his last few years of activity at the Canadian Museum of Nature, using results of the above-mentioned expeditions in various parts of

eastern Canada, his work on avian zoogeography focused on the ecological and historical distribution, taxonomy, and evolution of the many species of birds recorded on the mainland of Québec and Labrador as well as on adjacent islands. He was particularly interested in the fragments of tundra south of the tree line and the disjunct forest islands dispersed north of the tree line and in special areas which had been little studied, such as the northern part of Labrador, the western sector of the Ungava Peninsula, and Mansell and Akpatok islands. He was also studying the patterns of distribution of the Nearctic and Neotropical elements of the bird fauna of Canada in the light of recent distributional, palynological, botanical, and ecological information.

Henri was currently reviewing the status of several North American taxa, examining species limits and geographic variation patterns using standard taxonomic procedures such as biometry and statistical treatments, but also including newer approaches such as song analysis, keratin protein analyses, mitochondrial DNA, and PCR. At the time of his Ph. D. thesis and thereafter, part of his interests dealt with the relationships of the woodpecker genera *Dendrocopos* and *Picoides* (see *Ardea* 65:165–183; *Condor* 101:86–95, 1999). Throughout his career, he was particularly interested in studying various aspects of the biology (nesting, feeding and predato-

ry habits, pterylosis, etc.) of the Gray Jay (*Perisoreus canadensis*) (see *Canadian Journal of Zoology* 48: 327–330, 1970; 49: 147–158, 1971; *Canadian Field-Naturalist* 90: 5–10, 1976; *The Birds of North America*, Number 40, 1993), the species he chose as the official bird of the 1986 International Ornithological Congress (IOC).

Several years of study (*Wilson Bulletin* 105: 545–572, 1993) on the taxonomic status and distribution of the Gray-cheeked Thrush (*Catharus minimus*) resulted in the redefinition of the status of one population (*C. m. bicknelli*) to specific rank, Bicknell's Thrush (*Catharus bicknelli*).

Henri was also currently involved in a revision of the Neotropical genus *Sporophila* (Emberizidae: Seedeaters). He compiled the literature, examined a number of specimens in museums, and obtained specimens in French Guiana and Venezuela, making progress on pterylographic comparisons of 14 species, keratin protein analyses of 16 species, and collecting material suitable for DNA work on 12 species. Unfortunately, due to his premature death, this study remains unfinished.

Financed by Transport Canada from 1988 to 1992, he employed a technique using electrophoresis of feather proteins to identify bird remains trapped in propellers or other parts following collisions between birds and aircraft. This adaptation of known techniques to a new purpose produced excellent results and over 99% of the samples could be identified to the species level.

At the beginning of his career at the McGill Redpath Museum, Henri had been interested in establishing, standardizing, and publishing lists of French names for North American birds, and published a first list in 1968. More recently (1993), as co-chairman of the International Commission on French Names of Birds, he participated in the publication of "*Noms français des oiseaux du monde*" (Éditions MultiMondes Inc., Sainte-Foy, Québec). This publication and the criteria used for determining French names could ultimately serve as a model for preparing standardized lists of Portuguese and Spanish names for the birds of the Neotropical region. Finally, at his suggestion, a list of French names of North American birds has been included in the 7th edition of the *AOU Checklist of North American Birds* (see below).

Henri was the author or co-author of over 160 scientific and technical papers, including critical taxonomic revisions, over 40 peer-reviewed publications, various books/monographs and titles in collective works, 7 titles in museum bulletins, 8 papers in congress proceedings, over 45 book reviews, mainly in *The Canadian Field-Naturalist* and *The Auk*, and various non-peer-reviewed publications. As a much appreciated lecturer, he presented various public lectures throughout his career.

Henri's particular interest in the history of Canadian ornithology resulted in three publications: "Ornithology in Canada in the 20th century: a capsule overview," in *Bulletin British Ornithologists' Club* 100: 115–118, 1980; "Ornithology in Canada from the beginning to 1950" in *Acta XIX Congressus Internationalis Ornithologici*: 109–123, 1988, and "Ornithology at Canada's National Museum" (*Memoirs of the Nuttall Ornithological Club* 12: 303–322, 1995).

Henri was also involved in the training and supervision of several graduate students at the University of Montréal Department of biological sciences where, from 1993 until his death, he was "professeur associé.". At various other Canadian universities he served as external thesis examiner.

Henri was involved in miscellaneous ornithological and museological organizations, serving in various capacities on committees of these organizations and societies: Society of Canadian Ornithologists (President, 1994–1995); Standing Committee on Ornithological Nomenclature, IOC (member since 1982); Executive Committee of IOC (1990–1994); International Commission on French Names of Birds (Co-chairman, 1990–1994); World Wildlife Fund (Canada), Member of Scientific Advisory Committee, (1981–1988); Nature Conservancy of Canada (Scientific advisory board, 1990–1992); Committee on Status of Endangered Species in Canada (COSEWIC, chairman, subcommittee on birds, 1977–1982, member of executive committee, 1979–1989).

Henri joined the AOU in 1962, became an Elective Member in 1978 and a Fellow in 1984. Since 1983, Henri was a member of the committee on classification and nomenclature, which published various supplements to the 6th edition and then in 1998 the 7th edition of the *AOU Checklist of North American Birds*. Henri's task included the preparation of accounts for approximately 350 species of North American birds (particularly the plovers, sandpipers, swallows, corvids, Paridae, Certhiidae, Sylviidae, and Motacillidae) and the revision of the manuscript for all species known to occur in Canada. In addition, for the geographic/subspecies edition (8th) under preparation, he completed accounts for various genera of Picidae and for *Perisoreus canadensis*. He was elected a corresponding fellow of the Deutsche Ornithologen-Gesellschaft in 1988 and a permanent member of the IOC in 1990.

As an organizer he was outstanding. This showed throughout his career but notably in his efficiency in handling his heavy and prolonged duties as secretary-general and organizer of the XIXth Congressus Internationalis Ornithologici held in Ottawa in 1986. Preparation began in 1982 and his task extended until 1988 with the publication of two massive (over 2800 pages) volumes of proceedings. Under his

direction, the IOC conference in Ottawa was very successful and, among other consequences, launched the Society of Canadian Ornithologists (SCO).

Henri was friendly, courteous, and helpful to those he considered worth helping. He was a meticulous worker and was intolerant of sloppy work wherever he found it. His own office and laboratory were efficient and his was the tidiest desk on the floor. Good grammar and the use of the right word were always high among his interests. Indeed he was one of the few who could claim to be truly and completely bilingual. Little wonder, then, that he was chosen to translate Godfrey's *The Birds of Canada* into French. He worked with an unhurried but rapid efficiency and got things done. When he spoke up what he said was worth while. He had a good sense of humor and, in addition to studying birds, he was always "studying"

people. He was our friend and colleague and we will miss him very much.

Acknowledgments

For providing pertinent information we thank Michel Gosselin, and Richard Poulin, National Museum of Natural Sciences; C. Stuart Houston, University of Saskatchewan, Saskatoon; Richard C. Banks, Fish and Wildlife Service, U. S. Department of the Interior; Carla Dove, Division of Birds, Smithsonian Institution; Bruce MacKinnon and Gary F. Searing, Safety and Security, Transport Canada. We greatly appreciate the assistance of Yvette Testuz, Henri's widow, in locating various documents. A large part of Henri's books and data files are preserved at the Université de Montréal.



Henri Roger Ouellet, 1938–1999. Photograph taken in 1995 at the Canadian Museum of Nature, Ottawa.

Appendix 1: Summary of the educational and employment history of Henri Ouellet, his membership and positions in scientific organizations, and his field expeditions. Compiled by RAYMOND MCNEIL.

- 1951-1955: Externat Classique de Rivière-du-Loup (Affiliated to the Collège de Ste-Anne-de-la-Pocatière), supplying the first three years — “Éléments latins, Syntaxe, Méthode, and Versification” — of the 8-year “Cours classique”.
- 1955-1956: Collège de Ste-Anne-de-la-Pocatière (Affiliated to Université Laval “Belles lettres”)
- 1956-1958: Académie de Québec (Affiliated to Université Laval): B. ès L. (French and History): 1958.
- 1957, Summer: Student assistant in field work in New Brunswick (with Raymond McNeil) for Earl Godfrey, National Museum of Natural Sciences.
- 1958, Summer: Student assistant in field work in Knob Lake and Schefferville areas in Northern Quebec (with Raymond McNeil) for Earl Godfrey, National Museum of Natural Sciences.
- 1958-1962: B.A. studies in biology at the University of New Brunswick, Fredericton: B.A. 1962.
- 1959, Summer: Student assistant in field work in Newfoundland (with Raymond McNeil) for Earl Godfrey, National Museum of Natural Sciences.
- 1960, Summer: Student assistant in field work for Earl Godfrey in Newfoundland Labrador, National Museum of Natural Sciences.
- 1961, Summer: Student assistant in field work for Earl Godfrey on the Quebec North Shore of the Gulf of St. Lawrence, National Museum of Natural Sciences.
- 1962-1963: Research Assistant in Ornithology National Museum of Canada.
- 1963-1964: Contract work for the translation into French of “The Birds of Canada”, first edition.
- 1965: Chief Naturalist, Point Pelee National Park.
- 1965-1966: Assistant Curator, Vertebrate Zoology, Redpath Museum, McGill University, Montréal, Québec.
- 1966-1967: M.Sc. studies in zoology at McGill University, Montreal: M.Sc. 1967.
- 1967-1970: Ph.D. studies in zoology at McGill University, Montreal: Ph.D. 1977.
- 1967-1970: Associate Curator, Vertebrate Zoology, Redpath Museum, McGill University, Montréal.
- 1970-1976: Assistant Curator, Ornithology Section, National Museum of Natural Sciences, Ottawa.
- 1977-1986: Chief, Vertebrate Zoology Division, National Museum of Natural Sciences, Ottawa, Ontario.
- 1977-1991: Curator, Ornithology Section, [National Museum of Natural Sciences] Canadian Museum of Nature, Ottawa.
- 1977: McGill University, Montreal: Ph.D. in zoology.
- 1991-1994: Research Ornithologist, Canadian Museum of Nature, Ottawa.
- 1993-1994: Associate Researcher, Canadian Museum of Nature, Ottawa.
- 1993-1999: Professeur associé, Département de sciences biologiques, Université de Montréal, Montréal, Québec.
- 1994-1999: Researcher Emeritus, Canadian Museum of Nature.
- 1971: Province of Quebec Society for the Protection of Birds, Tchebec (One of the technical editors).
- 1972-1974: Ottawa Field-Naturalists’ Club (Council Member).
- 1972-1976: City of Gloucester Environmental Committee (Member).
- 1975: National Capital Commission Task Force on Mer Bleue (Member).
- 1975-1999: National Committee on Bird Hazards to Aircraft, Transport Canada (Member and Technical Advisor).
- 1976-1982: Committee on the Status of Endangered Wildlife in Canada (COSEWIC), Sub-Committee on Birds (Chairman).
- 1976-1986: COSEWIC (Representative of National Museum of Natural Sciences).
- 1978-1999: Committee on Feathers and Down, Department of Trade and Commerce, Standards Group (Scientific Advisor).
- 1979-1982: COSEWIC (Executive Committee Member).
- 1980-1986: Holarctic Avian Speciation Atlas, Advisory Committee (Member).
- 1980: Wilson Ornithological Society (Member).
- 1981-1988: World Wildlife Fund (Canada), Scientific Advisory Committee (Member).
- 1982-1986: International Ornithological Council (Secretary).
- 1982-1986: International Ornithological Committee, Permanent Executive Committee (Secretary).
- 1982-1986: International Union of Biological Sciences, Section of Ornithology (Secretary and Treasurer).
- 1982-1986: XIX Congressus Internationalis Ornithologicus [Secretary General (Elected in Moscow) and organizer of congress held in Ottawa in 1986].
- 1982-1999: Standing Committee on Ornithological Nomenclature, International Ornithological Council (Member).
- 1982-1999: International Ornithological Committee [I.O.C.] (Elected Member).
- 1983-1999: Society of Canadian Ornithologists (Founding Member; 1988-1989: Councillor; 1992-1993: President-Elect; 1994-1995: President).
- 1983-1999: Committee on Classification and Nomenclature, American Ornithologists’ Union (Member).
- 1988-1999: Deutsche Ornithologen-Gesellschaft(D-OG), Bonn, Germany (Corresponding Fellow).
- 1988-1992: American Ornithologists’ Union, Nomination Committee for Corresponding and Honorary Fellows (Chairman).
- 1988-1994: American Ornithologists’ Union, Committee on Research Collections, Sub-Committee on North American study skins collections (Chairman).
- 1990-1992: American Ornithologists’ Union (Member of Council).
- 1990-1992: Nature Conservancy of Canada (Member of Scientific Advisory Board).
- 1990-1994: International Ornithological Committee (Elected Member of Executive Committee).
- 1990-1994: International Commission on French Names of Birds (Co-Chairman).
- 1994: Advisory Board of International Project: The Birds of North America (Member).
- Membership and positions in scientific and professional organisations:*
- 1962-1999: American Ornithologists’ Union (1962: Member; 1978: Elective Member; 1984: Fellow).

Field work expedition for collecting birds for the National Museum of Natural Sciences (NMNS) and the Redpath Museum of McGill University:

- 1957, Summer: NMNS expedition with Earl Godfrey (accompanied by Raymond McNeil) to Anagance, Tracadie, Juniper and St. Leonard areas in New Brunswick: 902 specimens.
- 1958, Summer: NMNS expedition (accompanied by Raymond McNeil) to Knob Lake, Schefferville and Sawbill areas in Northern Québec and Labrador: 423 specimens.
- 1959, Summer: NMNS expedition (accompanied by Raymond McNeil) to Doyles, Witless Bay and Topsail Pond areas in Newfoundland: 817 specimens.
- 1960, Summer: NMNS expedition to Goose Bay, Cartwright, Nain and Makkovik areas in Labrador: 333 specimens.
- 1961, Summer: NMNS expedition to Havre St-Pierre, Blanc-Sablon and St-Augustin areas on the Québec North Shore of the Gulf of St. Lawrence: 381 specimens.
- 1963, Summer: NMNS expedition to the Anticosti Island: 377 specimens.
- 1965, Summer: Redpath Museum collection to the Mont St-Hilaire and area: 371 specimens.
- 1967, Summer: Redpath Museum expedition (accompanied by Jean-Luc DesGranges) to the St-Fidèle, Maria, Port-Daniel and Barachois areas in the Gaspé Peninsula: 273 specimens.
- 1968, Summer: Redpath Museum expedition (accompanied by Jean-Luc DesGranges) to the Mont Jacques-Cartier and Les Boules areas in the Gaspé Peninsula: 239 specimens.
- 1969, Summer: Redpath Museum expedition (accompanied by Jean-Luc DesGranges) to the Saguenay, Lac St-Jean and Abitibi areas in Québec: 281 specimens.
- 1970, Summer: Redpath Museum collection (accompanied by H. Hiemstra) in the Huntingdon area in Southern Québec: 180 specimens.
- 1971, Summer: NMNS expedition (accompanied by H. Hiemstra and Jean-Luc DesGranges) to the Great Whale River, Ruisseau du Pluvier, and Monts Otish areas in Northern Québec: 262 specimens.
- 1971-1972, Winter: NMNS expedition (accompanied by H. Hiemstra and Jean-Luc DesGranges) to the Forillon area in the Gaspé Peninsula: 37 specimens.
- 1972, Summer: NMNS expedition (accompanied by R. M. Poulin and M. Giroux) to the Cabbage Willows Bay, Lac du Tast, and Joutel areas in the Abitibi region, Québec: 364 specimens.
- 1972, Summer: NMNS expedition to the Pointe-au-Loup area on the Magdalen Islands, Gulf of St. Lawrence, Québec: 64 specimens.
- 1973, Summer: NMNS expedition (accompanied by H. Hiemstra and R. M. Poulin) to the Abloviak Fjord and Korok River area in Northern Québec: 264 specimens.
- 1974, Summer: NMNS expedition (accompanied by R. M. Poulin and G. Trencia) to the Fort Chimo and Leaf River regions in Northern Québec: 217 specimens.
- 1975, Summer: NMNS expedition (accompanied by R. M. Poulin and B. Lyon) to the Fort Chimo, Lac Ford and Coats Island regions in Northern Québec: 315 specimens.
- 1976, Fall: NMNS expedition (accompanied by R. M. Poulin) to the Pointe des Monts area in the Saguenay region, Québec: 83 specimens.
- 1977: NMNS expedition (accompanied by R. M. Poulin and R. Harris) to the Schefferville area in Northern Québec and Labrador: 212 specimens.
- 1979, Summer: NMNS expedition (accompanied by R. M. Poulin) to Sverdrup Pass, Alexandra Fjord and areas in North West Territories: 131 specimens.
- 1980, Summer: NMNS expedition (accompanied by R. M. Poulin) to the Phillips Bay area in the Yukon territory: 505 specimens.
- 1981, Summer: NMNS expedition (accompanied by R. M. Poulin) to the Cartyville, Cormack, Plum Point, L'Anseau-Clair areas in Newfoundland: 400 specimens.
- 1982, summer: NMNS expedition (accompanied by R. M. Poulin, C. Houle and G. Seutin) to the Rowanton area, Québec: 772 specimens.
- 1983, Summer: NMNS expedition (accompanied by R. M. Poulin) to Eastman River, LG-3, Lac Vincelotte, Fontanges, Lac Brisay and Lac Brion areas in Northern Québec: 540 specimens.
- 1985, Summer: NMNS expedition (accompanied by R. M. Poulin and D. B. Di Labio) to the Rockglen — Maple Creek areas in Saskatchewan: 718 specimens.
- 1986, Fall: NMNS expedition to the Guyane Française and Guadeloupe: 133 specimens.
- 1987, March: NMNS expedition to Venezuela: 45 specimens.
- 1988, March: NMNS expedition to Venezuela: 101 specimens.
- 1989, March: NMNS expedition to Guyane Française: 142 specimens.
- 1989, June: NMNS expedition to Mont Mégantic and Gaspésie, Québec.
- 1990, March: NMNS expedition to Venezuela: 62 specimens.
- 1990, June: NMNS expedition to Mont Mégantic and Charlevoix, Québec.
- 1992, August: CMN* expedition to Venezuela: 21 specimens.
- 1993, Fall: CMN* expedition to Argentina.

*On 1 July 1990 the National Museum of Natural Sciences became a federal Crown Corporation on its own was renamed "The Canadian Museum of Nature".

Appendix 2. Bibliography of H. Ouellet. Compiled by RAYMOND MCNEIL

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Book Reviews

ZOOLOGY

Rails: A Guide to the Rails, Crakes, Gallinules and Coots of the World

By Barry Taylor, illustrated by Ber van Perlo. 1998. Yale University Press, New Haven and London. 600 pp., illus. U.S. \$49.99.

This is yet another offering in the now familiar series of monographs on closely related bird groups or families. It follows the same format as its predecessors: an excellent and extensive introductory section provides a broad overview of the Rallidae, and then individual species accounts give concise yet comprehensive summaries of the information on each of the 133 extant species, plus 17 that are either recently extinct or that are probably so.

This series as a whole seems to cater to a birder audience by emphasizing identification and distribution, while providing good syntheses of other data on each species. In the present book, however, although there are indeed very comprehensive plumage descriptions, including sub-specific variation, and detailed accounts of range and status, I think I would have trouble pinpointing fine distinctions between species in the abundance of information provided — there is so much of it! It is the section on “Similar species” that will now fill this role. I compared this section’s coverage on the Little and Baillon’s Crakes, two very similar species that occur in Europe, and thought that it was good, providing significantly more useful detail than the standard guides.

Most of the difficulty with rails is seeing the things in the first place, not in identifying them. The task of finding them is made much easier with some understanding of their habitat and behaviour, and it is here that this volume excels. The author states that he hopes “this volume may also fulfil the role of a handbook in that it attempts to summarise the most significant aspects of the general biology and ecology of the species described”. He succeeds very well indeed, and this volume is probably the most detailed and comprehensive in the series so far. One rather crude comparison is that Melvin and Gibbs’ Sora account in *The Birds of North America* (Poole and Gill 1996), arguably the most authoritative reference currently available, is some 15 pages long, while the species has about 7 pages devoted to it in the present book, a very reasonable allocation.

Any work of this kind is necessarily the product of a massive literature survey, as the author cannot

hope to be familiar with all the species covered. The downside of this is that knowledge is very limited on many species in this elusive group, so the information provided is limited as well. This is most pronounced with those species that inhabit remote oceanic islands, but knowledge is lacking for even common species in North America. Coincidentally, at the time I was working on this review I looked at a window-killed juvenile Virginia Rail. The bird’s plumage was typically very dark, but it was relieved by the striking white edges to the forewing. This volume fails to mention anything about this feature, but it can hardly be faulted — none of my available North American books mention it either!

The 43 colour plates are the weakest part of the book. Here again they follow a familiar format, with similar species grouped, and short summary notes on identification and distribution for each species on the facing pages. On the whole the colours seem too pale, but some reddish shades appear to be both off in shade and far too bright, and some of the postures fail to capture the character of the bird. For example, I have never seen a Virginia Rail looking like the nominate adult on Plate 18, and while I have only ever seen one Black Rail, it certainly didn’t have the chestnut back shown on Plate 10, nor do any of my guides show a bird looking like this. It is also unfortunate that where the flight pattern is distinctive, more of the birds are not shown in flight. Rails do flush at times, and the white in the wing of a Yellow Rail, for example, is then diagnostic.

I detected a few other minor faults — for example, the first reference I checked (Poole and Gill) doesn’t appear in the Bibliography — but these criticisms should not detract from a fine achievement. This will now be *the* source book on rails, and it is packed with fascinating and useful information on this little-known group. It also makes for rather sad reading, as so many species are declining or endangered, but this really increases its importance, in providing a summary of available knowledge to support action to save these birds. In all, a volume that enhances an already fine series.

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Birds of Madagascar

By Pete Morris and Frank Hawkins. 1998. Yale University Press, New Haven, Connecticut. 316 pp., illus. U.S. \$35.

This is a no-nonsense bird book. With little preamble, it concentrates on depicting and describing the birds of Madagascar. Indeed, virtually all the book is devoted to the main topic. There is an introduction to habitat types and the distribution and conservation of birds and bird watching sites. While brief, these sections do impart the critical information needed. I was mildly surprised when the authors used almost three pages on the widely-available depictions of bird topography!

The remainder of the book is in standard field guide style. There is a description of two species on the left page and illustrations on the right. This is almost exclusively a photographic guide. The authors write that they chose photographs that portray the key features needed for field recognition. While this is generally true, there are some exceptions. There are nine additional, appealing paintings by Mark Andrews. For seven species, mostly rare endemics, this is the sole portrayal of the birds. For several other species (notably Rand's Warbler, Grey Emutail, Brown-throated Sand Martin, African Black Swift, Madagascar Spinetail, Madagascar Snipe, and Bat Hawk) the photographs are really too poor to be of use in identification. In other cases, while the photograph is good, a key component is obscure. For example, the crest on the Madagascar Cuckoo Hawk is not visible. In these cases there are no fill-in illustrations by an artist and this is unfortunate. Of the seven species quoted above, four are endemic. The three species to be found in nearby Africa are represented in some of the African texts.

English bird names in Africa can be variable and confusing. It took me a little while to realize the authors had split the Yellow-billed Kite from the Black Kite as a full species. I noted that they had moved the Thick-billed Cuckoo back to *Cuculus* from *Pachycoccyx*. Generally though, I had little difficulty associating a "Madagascar" name with those used elsewhere in Africa.

The descriptions are short but clear, and should allow for the confirmation of identification. I do not believe I could separate the endemic subspecies for such birds as Hoopoe and White-eye with the limited information given (except that they are on Madagascar). Extreme rarities, most of which are oceanic wanderers, are handled in appendices at the end of the book.

I have pointed out a few shortcomings of this book. It is important to remember that most of the 265 species covered have good photographs and are well described. I was impressed with the number of good flight photographs for most of the larger birds and some of the smaller ones. Virtually all photographs are of birds in the wild, only a few are hand-held banding specimens. Some of the photographs of more highly coloured species are quite superb. The visitor to Madagascar would find this a most useful book. The Malagasy birding community must be happy with this contribution to their culture. So, this leaves me with one last question. If the adjective from Madagascar is Malagasy, why are the birds called Madagascar Ibis, etc. and not Malagasy Ibis, etc.?

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A Field Guide to the Birds of Gambia and Senegal

By Clive Barlow and Tim Wacher. 1997. Yale University Press, New Haven, Connecticut. 400 pp., illus. U.S. \$40.

Gambia is a small English-speaking country of 11 000 sq. km and a population of one million. The closest comparison in Canada is PEI, which has 5 600 sq. km and 126 000 people (Nova Scotia is 55 000 sq. km). Senegal is a French-speaking country of 196 000 sq. km with a population of 8 million. Despite its small size Gambia has a rich avifauna, which it shares with Senegal.

This book is a fine new guide to this region. However, do not be misled by the title. This is much more of a Gambian guide than one for Senegal. Of the birds not illustrated (mostly rarities) a disproportionate number are from Senegal. In giving informa-

tion on status or distribution there is more detail on Gambian birds. That said, remember Gambia extends like a crooked finger into the heart of Senegal and, in general, both countries share the same species.

The introduction covers the basics of geography, climate, and vegetation for both countries. However, there is more information on the Gambia River flood plain than the drier rolling hills of Senegal. The author includes a listing of the nature parks and reserves.

The book's 48 colour plates are collected into one section. The artist, Tony Disley, has done an excellent job. The shape of each species is realistic and the colours are accurate. I was especially pleased that Disley depicted the correct sub-species wherever

appropriate. For example, the local sub-species of the Helmeted Guinea Fowl, *Numidea meleagris*, has a slightly different facial pattern and this is shown correctly. I spent considerable time verifying details on about a dozen species and found the illustrations to be correct for this area. I was a little surprised to see some birds shown in winter plumage only. For birds that nest in Europe and winter in this area, this makes perfect sense, however.

The text follows the plates and is also well done. It covers a description that includes a reference to similar species. "Habits" discusses the type of habitat as well as the actual habits. Voice, status, distribution, and breeding records round out the text. This section is also illustrated with black-and-white line drawings where the author feels additional material is required (gull plumages for example). The end papers have a map of Gambia and Senegal and two more detailed maps of Gambia.

I was puzzled not to find a number of species that I would expect, given the location and conditions. Birds such as White-throated Blue Swallow and Grey Parrot are missing. I was also surprised to find no reference to these two birds and to about five or six other species, not even as vagrants. I wonder if this is a reflection on difficulty of access, both physical and political.

I did my usual sampling of the index and found one error under Barbary Falcon (which in this book is split from Peregrine as a full species). But this is a minor error in a first rate book that is a fine contribution to bird literature. For the birder who has everything, this makes a great gift.

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A Kansas Snake Community: Composition and Changes Over 50 Years

By Henry S. Fitch. 1999. Krieger. Malabar, Florida. xi + 165 pp. illus. U.S. \$42.50.

Quite possibly no one has caught more snakes than Henry Fitch. Starting in 1948, Fitch began work on the snake community at the Natural History Reservation of the University of Kansas — now renamed the Fitch Natural History Reservation in his honour. Since that time, he has accumulated over 32 000 capture records on the 18 species of snakes that occur there. His project is the longest running study of any vertebrate community.

This new book concisely summarizes Fitch's data on each of the species of snakes found there. It begins with an overview of the study site and the successional changes that have occurred over the past half century and is followed by chapters of varying length on each species. Some chapters are only a page long, reflecting the rarity of that species at his site. For example, Fitch caught only a single Redbelly Snake during his work. The book concludes with an overall discussion of the snake community and the changes it has undergone.

There are many benefits to long-term studies, but one of the most important is the ability to determine the relationship between different factors. In a single summer, it is possible to determine the average clutch size of a particular species in a particular

place. Over 50 years, it becomes clear that reproductive success in Ringneck Snakes is positively correlated with spring rains. Ringneck Snakes are primarily earthworm predators and earthworms are more abundant in wet years. In fact, the humble earthworm (*Allolobophora caliginosa*) is the unsung hero of Fitch's book. Considering the entire snake community as a whole, earthworms were the most important prey species — by number and biomass.

During the course of the study, three species (Timber Rattlesnake, Bullsake, and Flathead Snake) disappeared from the site largely as a result of succession from pastureland to forest. An additional four species declined in abundance, but no species became significantly more abundant.

This is a major book in the natural history of snakes. It will disappoint those who are expecting a my-life-with-the-snakes memoir (which I hope Fitch is writing!) as it is largely lacking the anecdotal gems which often make species accounts more vivid. Nonetheless, it does provide an unparalleled insight into the changing demography and community structure of snakes.

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The Bird Almanac: The Ultimate Guide to Essential Facts and Figures of the World's Birds

By David M. 1999. Bird. Key Porter Books, Toronto. Paperback, xvii + 460 pp. \$24.95.

What a catchy title! David Bird calls his book *The Bird Almanac*, a play on his surname. His professed aim is to produce a book that simultaneously caters to "ornithologists, casual to serious birdwatchers, schoolchildren ... and those offering food to birds." One would think this impossible, especially since some tables and some terms are overly technical. Nonetheless this book packs so much information that portions should be of interest to all of the above!

Almost half the book consists of a list of the common and scientific names of every species of bird in the world, largely in the sequence of Monroe and Sibley (1990). This begins with the ostrich-rhea-emu-kiwi group, then proceeds (if one ignores some intervening groups that don't occur in North America) in turn to grouse, ducks and geese, and woodpeckers, which are inserted earlier than in any other classification. It ends with blackbirds. Since there is no index, those accustomed to standard classifications will search a long time to find, for example, the scientific name for a particular bird species of interest. Indeed, most of us do not need nor desire a list of all birds of the world.

Anatomy, physiology, and reproduction together occupy 41 pages. After four pages of general information about mortality and survival there are four pages about bird disease, two of state and provincial birds, and four pages of delightful Guinness-style records for everything imaginable (e.g., most songs sung: 22,197 in 10 hours by Red-eyed Vireo; countries with most endangered bird species: Indonesia 126 and Brazil 121; relatively largest egg: Little Spotted Kiwi, 26% of body weight).

The 32 pages of "Who's Who in Bird Biology and Conservation" will be of interest to many, but they should have been checked by someone with an interest in ornithological history and biography. There are

misspellings: Alexandre for (W. B.) Alexander, Streseman for Stresemann, and ridwayi for ridgwayi. E. A. Armstrong is listed twice. C. L. Bonaparte was the Emperor's nephew, not his brother. William Bullock died in 1849 and A. S. Neboux was born in 1806. Le Conte's Sparrow and Le Conte's Long-tailed Bunting are two names for the same bird. Clark and Lewis are listed as 'captain' and 'commander,' respectively, of the expedition they led jointly. Joseph Sabine was not a member of an arctic expedition, though his brother, Edward, was. William Tolmie was not head of the Hudson's Bay Company. For the next edition Bird might consider adding, among others, Ira Gabrielson, John Macoun, Howard Mendall, E.A. Preble, and George Wallace.

There are lists of presidents and award winners of the main ornithological clubs, lists of birding record-holders (P. Snetinger has observed 8040 species world-wide, R. Johns has seen 516 in Great Britain, M. Smith 840 in North America, and the late Norman Chesterfield 540 in Canada), and of bird carving and bird stamp awardees. Codes of bird-watching conduct for both the American Birding Association and the Royal Society of Birds are presented. There are tips for choosing binoculars, bird houses, bird baths, and backyard plants. Eighty-one pages list bird organizations, tours, journals, videos, web-links, telephone hotlines, telemetry gear, and companies offering DNA sexing, among other things. The book ends with a 34-page glossary.

This is a fun book to browse in. I predict that the second edition will be even better, with a binding that doesn't become unglued in the first week. The price is right! Buy a copy now.

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Pocket Guide to the Birds of Britain and North-West Europe

By Chris Kightley, Steve Madge and Dave Nurney. 1998. Yale University Press, New Haven. 300 pp., illus. U.S. \$20.

A well-written and well-illustrated guide treating the 385 species that occur regularly in Britain and North-West Europe. The birds are arranged in systematic order, that is closely related species are grouped together in genera and families. This is a widely-accepted format used in most birding guides. The 20-page introduction includes topics such as How to use this book, Bird topography, and What's in a name? The name of a bird is important. It con-

veys to others a magnitude of information. However, names can confuse those new to birding or any field of biology. A bird, in the ideal world, has two names, a scientific name and a common name. But many birds have several common names just in English and, less often, the scientific names can vary. For example, the common name warbler in North America refers to the family Parulidae, whereas in Europe their warblers are in the Sylviidae, and the orioles are Icteridae or Oriolidae, respectively. Some differing common names for the same bird in North America and Europe, respectively, are

Common Merganser and Goosander, Bank Swallow and Sand Martin, Oldsquaw and Long-tailed Duck, and Northern Harrier and Hen Harrier. In the text either one-half or a full page is devoted to each species. The data include highlights of the features distinguishing the bird from similar species, comments on nesting habits, calls, and food preferences. Several paintings illustrate the sexes, juvenile and winter plumages, and, in some cases, diagnostic features, such as the black V on the back of the smew's head. A short description explains each painting. A distribution map and comments on the status (such

as summer resident, etc.) and population of the species are included.

The authors have successfully packed a lot of information onto each 10 × 16 cm page. Although the principal emphasis is on Britain anyone planning on birding in Europe will find this guide most helpful.

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Cheating Monkeys and Citizen Bees

By Lee Dugatkin. 1999. Free Press, New York. xi+208 pp. U.S. \$37.

"The nature of cooperation in animals and humans", as this book is subtitled, has long been a subject of great interest to students in diverse disciplines, from animal field studies to human political analyses, and remains currently an area of very active research. What are we to make of a world containing both blatant selfishness and remarkable selflessness? Animal behaviourist Lee Dugatkin has prepared an up-to-date and highly readable account of the findings on this topic. He was stimulated by the trusting nature of his son, an admission with which any parent will sympathize.

The Introduction surveys the history of views on cooperation, highlights divergences such as that between T. H. Huxley and Peter Kropotkin, provides a few examples with implications for humans, and outlines four pathways to cooperation, each of which receives a chapter. Kin selection is reviewed by focussing on haplodiploid hymenoptera, naked mole rats, dwarf mongoose, helpful birds, and human step-relations. Reciprocation is presented through games theory, hermaphrodites trading eggs and sperm, primate coalitions, and exchanges of food and grooming. By-product mutualism, understood as enlightened selfishness in a social context, is involved in activities ranging from group foraging, crying wolf, and mobbing predators. Finally, the thorny matter of group selection is tackled both historically and by examining cases such as honeybees as possible

superorganisms, reactions to predators in guppies (which Dugatkin has studied), and the dynamics of Hutterite communities. In this chapter it is obvious why group selection remains a difficult domain both theoretically and empirically, and likewise possible impact for understanding humans. Even jointly, data and logic do not enable choices among alternative interpretations.

By way of conclusion Dugatkin suggests useful lessons for our species which can be rationally drawn from animal evolution. The chapters thus sensibly cover pathways which are increasingly controversial. Throughout there is reasonable reflection on possible implications for humans, such as the social impact of extended families, the role of such factors as hard times, and the positive and negative aspects of tribalism. The thoughtful reader pondering these considerations will realize how complex are our social problems.

The text is unfortunately not illustrated but written in a lucid and friendly style. Overall Dugatkin's book provides clear analyses of the complex issues of selfishness and cooperation plus useful speculations on implications for human society. It merits reading by everyone who cares about cooperating: which should be everyone.

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BOTANY

Shinners & Mahler's Illustrated Flora of North Central Texas

By George M. Diggs, Jr., Barney L. Lipscomb, and Robert J. O'Kennon. 1999. *Sida Botanical Miscellany*, No. 16, Botanical Research Institute of Texas, 509 Pecan St., Fort Worth, Texas 76102-4060 USA. 1626 pp., illus. U.S. \$89.95 + \$7.42 tax + \$7.50 shipping.

This book with over 1600 pages and good hard covers weighs a ton and I would not want to carry it in a packsack while out in the field studying the vegetation. It does however contain a wealth of information and will be invaluable when identifying plants of the northern central part of the state of Texas. It "is the first publication of the Illustrated Texas Floras Project, a collaborative project of the Austin College Centre for Environmental Studies and the Botanical Research Institute of Texas to produce illustrated floristic treatments designed to be useful to both botanical specialists and a more general audience", and is dedicated to Lloyd H. Shinners and William F. Mahler for their contributions to Texas botany.

The first 75 pages are devoted to an Overview of the Book, Geographic Area Covered, Information Helpful in Using the Flora, Summary Data on the Flora, New Combinations made in this Book (*Gutierrezia amoena*, *Mirabilis latifolia*, and *Manfreda virginica* subsp. *lata*), Author's Note (a request for corrections, comments and specimens that would be helpful for improvements to a future edition), an overview of North Central Texas (Geology, Soils, Climate, Blackland Prairie, Cross Timbers and Prairies, Red River Area, Origin of the North Central Texas Flora, Conservation in North Central Texas, and a Sketch of the History of Botany in Texas with Emphasis on North Central Texas). This is followed by 32 pages containing 174 excellent colour pictures.

In this volume a total of 168 families comprising of 854 genera and 2223 species (1829 native and 394 introduced) are found in an area encompassing 40 000 square miles ($\approx \pm 103\,600$ square kilometers), about 46% of the species in Texas in about 15% of the land area.

The main text begins on page 109 with keys to major plant groups: Lycopodiophyta, Equisetophyta, Polypodiophyta, Pinophyta, Gnetophyta, Dicotyledonae, and Monocotyledonae, Keys to Ferns and Similar Plants, Keys to Gymnosperms, Keys to Aquatic Plants, Keys to Monocots, and General Key to All Families. The General Key is modified from Key and Descriptions for the Vascular Plant Families of Oklahoma (Tyrle et al. 1994) to which numerous couplets have been added to cover plants which occur in North Central Texas, but not in Oklahoma, but no couplets have been deleted from the Oklahoma family key, thus making it useful to both Oklahoma and Texas users.

Within each of the groups listed above, the families, genera and species are in alphabetical order. This

main text, in addition to detailed, easy to read descriptions of all levels is full of interesting notes. An excellent example may be found in the text of the common weed *Capsella bursa-pastoris* "(shepherd's purse, the fruits resembling the scrotum of a sheep used as a purse by shepherds) ... first seen in Dallas Co. in 1865 ... Used medicinally by Chinese for eye disease and dysentery; apparently used by humans for 1000s of years — collected seeds have been found at an ancient site nearly 8,000 years old. The seeds of Shepherd's Purse appear to be carnivorous; a chemical released by the seed appears to attract organisms such as protozoans, nematodes, or mobile bacteria; subsequently, an enzyme secreted by the seed digests the protein to absorb the material". Many supporting references are cited and seven symbols which are first listed together with their meaning on page 14 may be found throughout the text: endemic to North Central Texas; endemic to Texas; family or generic synopsis; introduced species, subspecies or variety; endangered or threatened taxa — a TOES rating is also given for such taxa; toxic/poisonous plant; and colour photograph provided — page number follows symbol. Excellent line drawings, several to a page may be found following the descriptions for all the species in the text.

The main text is followed by a number of useful appendixes: 1. Phylogeny/Classification of Families of Vascular Plants of North Central Texas; 2. Subfamilial and Tribal Phylogeny/ Classification of North Central Texas Poaceae (Grass Family); 3. List of Texas Endemics Occurring in North Central Texas; 4. Illustration Sources; 5. List of Selected Botanically Related Internet Addresses; 6. Taxonomy, Classification and Debate about Cladistics; 7. Changes in the Scientific names of Plants; 8. Collecting Herbarium Specimens; 9. List of Conservation & Environmental Organizations in North Central Texas; 10. Larval Host Plants of Lepidoptera of North Central Texas; 11. Books for the Study of Texas Native Plants; 12. A Suggested List of Ornamental Native Plants: Trees, Shrubs, Vines, Grasses, Wildflowers; 13. List of Sources for Native Plants; 14. State Botanical Symbols; 15. Special Recognition — Benny J. Simpson; plus a Glossary, Literature Cited, a very easy to read Index, and information regarding the authors and their institutions.

This is a tremendous book and the authors and their supporters should all be congratulated for their efforts in its production.

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Gleason's Plants of Michigan: A Field Guide

Revised by Richard K. Rabaler. 1998. Oakleaf Press, Ann Arbor, Michigan. 398 pp., illus. U.S. \$21.95 + \$3.50 shipping + \$1.32 tax in Michigan.

This field guide will be most useful to any naturalist studying plants in Michigan and surrounding areas. It consists mainly of easy to read keys, the first of which sends the user to sections Group 1: Plants; Group 2: Unusual Plants; Group 3: Monocots; and Group 4: Herbaceous Dicots. The first two Groups will lead one either to a genus or an individual species of the family to which the plant being keyed may be found in Group 3 or 4.

The initial pages include an Editor's Note which describes this book as a substantial revision and expansion of *The Plants of Michigan* by H. A. Gleason (1918) in which the original format has been retained but most of the keys have been completely rewritten and expanded. It follows the

arrangement and definition of families used in Voss's *Michigan Flora* (1972, 1985, 1996). This is followed by a Table of Contents, a preface describing Gleason's Michigan Period, Acknowledgements, an Introduction which describes how to use the book, a bibliography, terminology used in plant descriptions, and a list of illustrations. A glossary and an index to plant names completes the work.

This is a most welcome work which will be helpful in the field to anyone interested in plants in the Michigan region.

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ENVIRONMENT

Costa Rica: The Ecotraveller's Wildlife Guide

By Les Beletsky. 1999. Academic Press, San Diego, California. 426 pp., illus. U.S. \$27.95.

This book is a very fine purchase. In fact, it is two books for the price of one. The first book is the one the author intended. He introduces tropical Costa Rica and its wildlife inhabitants and raises enthusiasm to visit this lush country. In doing so he overtly promotes ecotourism and raises the profile of conservation.

Dealing first with the Costa Rican component of this book, the author has selected those animals and plants that will most likely be encountered by the ecotourist. Therefore, this book is not an exhaustive account, but is limited to the more common or more visible species. He includes reptiles, amphibians, mammals, and birds. He does not include fish, butterflies, and other insects and only a handful of the higher plants. The chapter on ecotourism, geography, climate, habitats, and major parks is an excellent introduction for the visitor; particularly for the first time visitor. A following chapter on conservation in Costa Rica is also instructive and provides information that should be part of our understanding.

About 75% of the book is a field guide section. This is divided into two equal halves; the first is a written description of the groups and species illustrated. In each introductory section the author describes the order-family structure, how many species there are worldwide and how many occur in Costa Rica. Much of this information, while fascinating, is not relevant to the ecotourist in Costa Rica.

Beletsky does the same thing in the section on status. He uses as much space on endangered species in other parts of the world as he does on Costa Rica. He recounts a number of bird legends, again from around the world. Some of these legends are really charming. He also gives valuable details on the species covered, providing insights and understanding that will be valuable in the field.

The illustrations are provided by four artists, one for black-and-white line drawings of plants and one each for the coloured plates of the reptiles and amphibians, birds and mammals, and are all good quality. The bird plates reminded me, in both quality and style of Roger Peterson. I thought the amphibian plates were particularly endearing.

As this is a tropical country Beletsky considers the potential dangers visitors might face from poisonous frogs, venomous snakes, jaguars and the like. His approach is based on good common sense rooted in realistic possibilities. That is to say your chances of having a problem are very low. Additionally, he particularly cautions about mosquitoes, ticks, bees, heat, and traffic. These latter are the creatures and conditions that have given me all the problems I have encountered in the wild.

Within the text on Costa Rica lies an introduction to Natural History 101. It is like listening to a seasoned naturalist tell about an area he truly loves, yet cannot resist adding in anecdotes and information from all his other experiences. This additional, non-Costa Rican material, at first annoyed me. It got in

the way of doing what I wanted to do; getting to know Costa Rica. The more I read, the more ameliorated I became. Although I still find it more difficult to see the direct contribution of the chapters on eco-tourism in general, basic natural history and ecology, and conservation in all of Latin America to my understanding of Costa Rican ecology. There are also several essay-like sections on frog populations, the temperature relationship between turtle eggs and sex, frugivory (fruit eating), and bird promiscuity and species numbers in the tropics. Because they are well written they are interesting to read, but I still question their contribution to meeting the book's title. By the end of the book, though, I was very glad I had read all the way through. The peripheral material is a well-written introduction to the study and enjoyment of nature.

Les Beletsky is a recognized scientist and professor. So I was surprised by the handful of errors I

found. These ranged from an inconsistent use of Red-eyed Leaf Frog and Red-eyed Treefrog to a persistent confusion between poisonous and venomous (rattlesnakes are not poisonous — people eat them often — they are venomous). There was also a curious reference to non-mammalian humans!

In summary, I would suggest this is a must for the first time visitor to Costa Rica, a good buy for visitors to central America and entertaining reading for newcomers to natural history study. I would encourage Les Beletsky to write a stand-alone introduction to general natural history. His clear style and sense of humour would give novices an easily-read introduction to their new-found hobby.

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Habitat Creation and Repair

By O. L. Gilbert and P. Anderson. 1998. Oxford University Press, Oxford. 288 pp., illus. \$49.95.

In a world of decreasing number of habitats undisturbed by human activities a need for habitat repair and creation has developed. Some would argue it is better to conserve present remnants of habitat rather than create simplified versions. Unfortunately, undisturbed habitats are no longer in existence for all ecosystems. Newly created simplified ecosystems also may have the added benefit in providing a buffer for remaining undisturbed ecosystems. These issues and the methods to increase success are addressed in Gilbert and Anderson's book *Habitat Creation and Repair*.

The book is meant to be a handbook for practitioners concerned primarily with habitat creation on bare or simplified sites. The handbook is divided into eight chapters covering ethics, role of habitat creation, general principles, promotion of succession, and specific considerations for seven specific habitats. The reader is provided a list of references after the chapters. The majority of references originate in the British Isles. For quick references there are also a subject index and a glossary of forty-three terms. Throughout the text case studies are provided in

boxes separate from the text. This provides a very readable and easily referenced handbook.

A great deal of effort is spent outlining requirements for a successful project. There is a decided shift from engineering solutions to the biological. The reader may encounter some difficulty with technical designations of communities. The designations are British Isles specific and do not relate to the Canadian terminology. Greater use of North American and other international references would provide a more global approach.

Despite the strong British Isles bias, Gilbert and Anderson do provide a book which contains guidelines for all practitioners no matter their location. The hints presented should be valid no matter the locale. The reader benefits from the British experiences relayed in the book and is also provided an insight of the level of development in habitat creation and repair found in the Isles. *Habitat Creation and Repair* should prove to be a valuable reference to those involved in this endeavor.

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International Environmental Consulting Practice: How and Where to Take Advantage of Global Opportunities

By P. A. Sam. 1999. John Wiley and Sons, New York and Etobicoke. xv + 300 pp., illus.

This is a good reference background book for those interested in international environmental consulting. At the same time, it is mostly very general in its coverage, while more specific sources are available, and it is not very up-to-date. One can obtain much more recent data from the World Bank publications (which Sam works for) or the Canadian Foreign Affairs web site. Sam has no references in the bibliography past 1995 and no references at all to internet sources. Many countries have their own web sites with great sources of data, as do the international financial sources (World Bank, Asia Development Bank, African Development Bank, CIDA, US AID, etc.), and others available through a simple web search. For Canadians, the Foreign Affairs IFI net (www.dfaitmaeci.gc.ca) provides free access to most of these other web sites as well as an up to date listing of projects available. The next best source would be the Business Development news from the United Nations at US\$500 per year. Neither of these is mentioned by Sam.

The eight chapters of the book are largely general and philosophic in their content. They are good background for someone new to the field, but do not provide the information really needed for success in international consulting. Most experienced international workers would not gain much from them. The theme is largely from the United States perspective (although Sam is originally from Ghana) and assumes that foreign countries are behind in technology and need Americans to teach them and show them how. In 25 years of international environmental consulting, around the world, I have found that most developing countries are behind in technology only because of financial needs, but have the education and capacity to do the work. My Nigerian company (www.geoniger.com) is now doing environmental, satellite remote sensing, and GIS work from as high a technology approach and capability as any Canadian, European, or United States consultant. I am the only non-native out of twenty employees. I think few Canadians would agree that "It is apparent the US leads the world in environmental technology and management".

Teaching developing countries to do it the American way is also something I disagree with. Dr. Osman Sankoh, who founded and is editor-in-chief of the African Journal of Environmental Assessment and Management, writes: "developing countries have an enabling environment for implementing EIAs as long as they are not largely tailored to reflect west-

ern stipulations" (Journal of Environmental Management (1996) 47: 185). The Canadian Government has long emphasized the policy of using local Native knowledge for environmental management in the north. I have found the same essential in developing countries.

Over half of the book is in the 19 appendices and bibliography. These should be an essential source of data. They are relatively limited overviews of the topic and do not provide references to sources for more up to date or detailed information. A book written in 1999 should have more recent data than 1992. Much of this data is updated annually by the World Bank and available on CD. Checking some of the areas where I am currently working, I also found errors or information missing. For example, the list of environmental institutions in Nigeria does not include the Federal Environmental Protection Agency which up until the most recent change in government was the equivalent of a ministry of environment. The Ministry of Petroleum Resources, who have implemented EIA requirements for many years, are not mentioned. Most addresses given are in Lagos, while the Nigerian Government moved to the new capital of Abuja many years ago. Some countries (Romania) are missing from the list. Data on changes in vegetation and ecozone was without detail and missed some recent work, including my own (Overview of the land use and vegetation change analysis study for Nigeria between 1976 and 1995. Workshop proceedings, May 1997, Abuja). Admittedly this was an obscure workshop, but the project was sponsored by the World Bank, the World Bank had representatives in attendance, and Sam works for the World Bank. Tables in our presentation have detailed analyses of the changes which have occurred.

Generally a book of this nature is a challenge to keep up to date and detailed. I think Sam has done a good introductory job for those contemplating an international consulting future. I would recommend research into much more recent and detailed data sources before leaving Canada or the USA. Sam's best advice is where he recommends local partnerships with someone who can ensure you do not do the wrong thing. I have found this the most successful approach.

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Ecological Scale: Theory and Applications

Edited by D. L. Pearson and V. T. Parker. 1998. Columbia University Press, New York. 615 pp., illus. Cloth U.S. \$69; paper U.S. \$40.50.

Ecological Scale is an edited volume of papers dealing with the currently hot topic of spatial and temporal scale. The book is part of the *Complexity in Ecology* series edited by T. F. H. Allen and D. W. Roberts and published by Columbia.

The book has 22 chapters divided into four parts: (1) Integrating pattern, process, and scale; (2) Interpreting multiple scales in ecological systems; (3) Moving across scales; and (4) Incorporating scale concepts in ecological applications. This is an edited volume of contributions, so a diverse array of subject matter is covered including paleoecology, forest management, population ecology, landscape ecology, and remote sensing, among others.

In chapter 1, O'Neill and King set the table for the rest of the book by placing *Ecological Scale* within the context of other books on scale. Much of the chapter is an attempt to clarify the difference between "level" and "scale": a level is definitional and scale-independent, whereas scale implies a measurement. The authors suggest that the phrase "landscape-level" is too often used without discretion. This is straightforward, sensible stuff — so it seemed unnecessary for Allen to spend chapter 3 clarifying the exact same relationship (i.e., level vs scale). After all this, two subsequent chapters (11 and 16) include the phrase "landscape-level". The confusion is, in part, a byproduct of a contributed volume.

Overall, the book contains some excellent chapters. In particular, there is a nice introduction to the spatial scaling of animal population dynamics (chapter 9), some interesting ideas about allometric and isometric rescaling (chapter 12), and excellent chapters about incorporating scale into study design and data analysis (chapters 17 and 18). However, there is some overlap between Dutilleul's data analysis chapter (18) and Gardner's chapter 2 (Pattern, process, and the analysis of spatial scales). The level of detail in these chapters ranges from introductory to highly specialized.

In the preface, the editors state that the book's objective is to create a greater awareness of the need to incorporate scale concepts into ecological studies and applications. Frankly, this objective is too limited: ecologists are beyond it. Now we need to know how, when, and why we should incorporate scale into studies and applications. This book is certainly a step forward, but in my mind it raised more questions than it answered. I came away with the feeling that there is yet much to be learned about dealing with scale. I think this is a true reflection of the state of the subject matter.

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Nature in Ireland: A Scientific and Cultural History

Edited by John Wilson Foster. 1997. The Lilliput Press, Dublin, and Dufour Editions, Chester Springs, Pennsylvania 19425-0007. xiv+658 pp., illus. U.S.\$39.95.

This is an impressive volume. Editor Foster, who divides his time between the University of British Columbia and Co. Down, has brought together an eclectic array of authors to treat a wide variety of topics. The principal objectives were to develop an integrated view of history, culture and nature, and to rehouse natural history in Irish culture. "The history of habitats, ..., is also unavoidably a history of culture and society, involving the utilization and exploitation of nature as well as its study." The book argues for both the discarding of our view of nature as *The Enemy*, and for a much greater integration of nature into human culture. "Nature and culture have traditionally been regarded as opposites, but the study of nature is the bridge between them."

Twenty-nine authors contributed to the 26 chapters. There are 43 black-and-white photographs on

20 glossy plates and 13 more scattered in the text. Two maps of Ireland show the county boundaries and county seats, and the main river systems and mountains.

History is a major part of the volume. There are no lists of fauna and flora, but considered discussions of the study of nature. Chapters treat geology, botany, insects and entomology, mammals and mammalogy, bird study, fish and fisheries, meteorology, major surveys, and mapping of the physical geography. These are intermixed with discussions of nature illustration, essential natural history texts, Darwin and the evolution debate, early naturalists, threat and conservation, traditions, etc.

Canadians will be particularly interested in the chapter titled *Out Of Ireland: Naturalists Abroad*, because several of the men spent considerable time in Canada or in Canadian waters. W. S. Spotswood and Henry Swanzy were commissioned by the Canadian government in 1888 to survey the peaks

and glaciers of the Selkirk range of British Columbia. The reports of the John Palliser Expedition of 1857-59 were for some time the major source on the country from Lake Superior to the Okanagan Valley of British Columbia. Francis Beaufort, after whom the Beaufort Sea was named, although he never visited Canada, was responsible for British government supporting expeditions into Arctic waters in the early 1800s. F. L. McClintock of the British Navy was from 1848 to 1859 associated with the searches for the lost Franklin expedition. He developed the technique of long-distance sledge journeys, using man-hauled sledges and was leader of the team that resolved the fate of Franklin. And John Macoun's contributions to the settlement of the West and to the Canadian flora as naturalist/botanist in the Geological Survey of Canada are summarized.

Hunting, forestry, and land management are the subjects of several closely woven chapters. In *Wild Sports and Stone Guns*, author Viney traces the development of the hunting sports. So important was the honour that pagan hunters accorded their prey that the Deer God of Celtic mythology was incorporated into early Christianity. Hawking, hunting, racing, shooting, and foxhunting have been important events for centuries. For the native Irish some were urgently connected with fending off starvation. For the colonizers they were sports. The physical landscape, its openness, shaped much of Ireland's field sport. Money and religion determined the participants in field sports.

Closely integrated with the field sports was the *demesnes* (that part of the manorial estate not leased out to tenants but retained by the lord for his own use and occupation). Deer Parks (perhaps better titled Hunting Parks), introduced in the 13th century by the Normans who imported the fallow deer, were the first *demesnes*. Initially they were to supply much of the meat consumed at the Big House.

Demesnes were subjected to landscaping. Today a visitor to Ireland tends to think of stands of large beech, etc. and rolling pasture as natural because they are obviously old but most were man-made. Plantings of laurel and rhododendron to provide cover for pheasants began when the shotgun was introduced with which "game" could be shot in flight. Woodland strips were often planted for driven shoots and landscape parks were designed with shooting rather than picturesque ideals in mind. Pheasants, partridge, and woodcock were the principal species hunted. Eradication of "vermin" foxes, badgers, pine martins, cats, and even otter was ruthless. While foxes were vermin if inside the *demesnes*, outside they were encouraged to live and breed to provide targets for fox hunting. For many centuries *demesnes* dominated developments in the Irish landscape. Today, their social and economic role has gone, but despite wholesale destruction via

subdivision, they remain the most significant man-made feature of the landscape.

Ireland has been an island for 7500 years. What was it like when "man" arrived? Open pine woods flourished in the cooler west and on high ground everywhere. As Feehan states "The dominant theme in Irish history from that time on was the retreat of the wild." Despite destruction of forest land for agriculture for a thousand years as late as the 12th century the country was still clothed in trees. The Normans began the export of timber to England. During the Tudor conquests the forests were destroyed to deprive opposition armies shelter. Charcoal production depleted vast forests as did the demands of the shipbuilding industry. Thus "the substantially forested Ireland of 1600 had by 1711 become a treeless wilderness and net importer of timber" (Neeson). When the forests were gone so were the plants and animals that were dependent upon them. Other habitats were not immune. Bogs and marshes were, centuries ago, considered wasteland. Extensive drainage in the early 19th century, compounded by hunting, has meant the bittern has not bred in Ireland since about 1840. A revived interest in forestry by the landowning elite came to be seen by the deprived peasantry and smallholders not as a means of reviving a natural national capital asset, but as yet another means of depriving them of the use of land rightfully theirs (Neeson).

Myth and religion are closely associated with our picture of Ireland. Several discourses develop the relationships between them and nature, often with a liberal sprinkling of politics. Myth and reality were often intermixed in the early natural history writings. The observational or experimental approach of nature study which leads naturally to questioning authority inevitably threatened the great institutions. In Irish cultural lore the scientist was dramatized as a homologue of the despised colonist. Botanical exploration prior to 1800 was hindered because the country was often in turmoil and wandering botanists were treated as spies sent by the enemy. Nevertheless, the first national flora appeared in 1833 and although published anonymously, was apparently written by Katherine Baily at the age of 22.

There are many more fascinating topics in the book. For example, the importance of geology (the geological term *eskers* is from the Irish); the incomprehensible early manuscripts in Irish; the churches and yews; the Barnacle Goose myth; the early naturalists, Augustine and Giraldus; the effect of the Industrial Revolution; the distilling of buzzard's feet as a cure for sciatica; and many more.

I continually sought examples from Ireland that paralleled contemporary situations in Canada. Unfortunately, we are repeating history, making the same mistakes in exploitation and fumbling along

with expensive rehabilitation projects. All is not doom and gloom, Feehan in *Threat and Conservation: Attitudes to Nature in Ireland* emphasizes the new sense of value and meaning in nature. It comes from two directions: membership in the European Community with an influx of funding, and the Catholic Church. The "New Theology" claims a moral perspective for environmental awareness, grounding it in our responsibility to appreciate the natural world as God's first revelation, before all written scriptures, and to respect and preserve the goodness and integrity of God's earth, for which we are answerable.

After visiting the west coast of Ireland and seeing its varied and impressive geology, e.g., the Cliffs of Moher, Fanore dunes, Black Head and the Burren pavement, and the unusual flora, I recommend this book to all naturalists and travelers. You will be pleasantly surprised by its variety and lucid writing. A wealth of information is presented and the bibliographies direct you to many old and new works.

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The Dawn of Conservation Diplomacy: U.S.-Canadian Wildlife Protection Treaties in the Progressive Era

By Kurkpatrick Dorsey. 1998. University of Washington Press, Seattle. xvi + 311 pp., illus. U.S. \$35.00.

In the present era of multinational commissions and conventions on globally important topics such as population growth, climate change, sustainability, and biodiversity conservation, it is easy to lose sight of early international attempts at conservation diplomacy. This book presents three case studies of attempts to develop conservation treaties between Canada and the USA between 1890 and 1920. The three case studies highlight important aspects of circumstances of politics, diplomacy, advocacy, science, economics, philosophy, and public perceptions that led to success or failure. Although the negotiations that led up to these treaties occurred almost a century ago, it is clear that many of the same sorts of issues, attitudes, and perceptions are pervasive and relevant today, and therefore, history can continue to inform us and to provide insights into the pitfalls and strengths of various approaches to treaty development. The lessons learned from these case studies should be applicable to domestic conservation legislation and regulations, as well.

The first treaty examined is the Inland Fisheries Treaty of 1908. This treaty covered the shared fisheries of the Great Lakes, Puget Sound, Lake of the Woods, Passamaquoddy Bay, the St. Croix River, Lake Champlain, and Lake Memphremagog. Tensions between American and Canadian fishermen, and subsequently politicians, existed because of the lack of uniform regulation of the fisheries, overexploitation, and differential market prices. Superimposed on these factors was the increasing level of pollution in many of the shared water bodies, which was contributing to the declines in commercial fish populations, making these fisheries unsustainable. The attempt by the two nations to develop a treaty was precipitated by these factors with the hope that a common set of rules would resolve the dispute and save the fisheries. Several

attempts (both scientific and diplomatic) were made to establish some joint form of understanding over the shared fisheries, and eventually, after about sixteen years of initiatives and negotiations, the Inland Fisheries Treaty was ratified. However, as Dorsey explains, in the end, the treaty failed for several reasons. These included the lack of willingness on the part of the American government and American fishermen and commercial interests to accept more stringent restrictions on their industry, as well as the failure of scientists (with a few exceptions) and conservationists to rally to the defence of the resource. Another difficulty may have been the broad range of fisheries and disparate geographic areas covered by the treaty. Each type of fishery required its own solutions (seasonality, types of fishing to be permitted, catch limits), which made the development of regulations under the treaty extremely complex. Efforts to develop regulations continued for six years after ratification of the treaty, but were never completed.

The North Pacific Fur Seal Convention of 1911 is the second case study presented in this book. In the 1880s, major declines in populations of the North Pacific fur seal began, as Canadian sealers began killing seals on the high seas. Prior to that time, sealing was confined largely to the American-owned rookery islands (Pribilofs). A few smaller rookeries occur on other islands in the Bering Sea and North Pacific Ocean. Sealing on land allowed for discrimination in the types of animals being harvested, with an emphasis on immature (non-breeding) males, thereby minimizing the impact on the breeding population. As it turned out, these young males also possessed the best quality fur, from a marketing perspective. However, on the open seas, many of the animals killed were females, including nursing females. Thus, pelagic sealing was extremely damaging to populations. The development of a treaty to conserve fur seals fared better than the Inland

Fisheries Treaty for a couple of reasons. First, seals, and especially young seals, were considered to be cute and harmless by the public, and therefore, it was easy to appeal to human sentiment in calls for protection, and particularly, for cessation of pelagic sealing, which was resulting in numerous orphaned and starving seal pups. Second, because fur seals were concentrated on relatively few rookery islands, it was easy to obtain relatively accurate information on population trends and other aspects of their life history, leading to agreement between the Americans and Canadians on the need to conserve the seals. In spite of these factors, it still took twenty-five years to complete and ratify the treaty (with Japan and Russia also as signatories). The stories of the negotiations and the individuals involved in them (some of whom were seal experts and some of whom only considered themselves to be so) are fascinating. This case study provides insights into how scientific evidence and public opinion were combined with diplomatic efforts to yield a conservation agreement.

The Migratory Bird Treaty of 1916 was perhaps the least contentious of the three treaties presented in this book, although even in this case, economic interests, particularly in the USA, lobbied against it, supported by their state governments. Nevertheless, the general public appeal of birds, the feeling that people had a moral obligation to save interesting and useful species, and the concurrent demise of the Passenger Pigeon and major reductions in the populations of birds hunted for the feather/fashion industry and for food resulted in a broad base of support for bird protection. This public support, coupled with scientific evidence, and war-time (First World War) economic arguments about birds as important agents safeguarding agricultural crops by their consumption of insects, resulted in a strong and effective lobby in favour of this treaty that could not be overcome by the state's rights, market hunter, and "game hog" (hunters who killed as many birds as possible, regardless of time of year, without regard for conservation) lobbies. It is interesting to note that sport hunters, who abided by the conservation ethics of the time, and considered their sport to be a gentlemanly

pursuit where restraint was "... the key to appropriate hunting behaviour" (page 173), were a major supportive component of the protectionist/conservationist lobby. In his discussion of the development of this treaty, Dorsey covers various subjects, including the establishment of the National Association of Audubon Societies, legal challenges to the constitutionality of federal laws regulating resources that were perceived as falling within state's or province's jurisdictions, and the personalities of some of the major proponents and objectors as they related to the development of the treaty. He also indicates that the Americans initially were inclined to negotiate a bird conservation treaty with Mexico, since many of their birds migrated to, and wintered in, Mexico or other Latin American countries. However, Mexico was still politically unstable at the time, and did not yet support a conservation movement. Thus, Canada was a second choice. Nevertheless, the final result of the negotiations, the Migratory Bird Treaty, has endured to the present day. It "... became the first broadly effective wildlife conservation treaty" (page 237).

This book provides a fascinating and informative account of three attempts at the development of conservation-oriented treaties between Canada and the USA. It is easy to read, and the background information about the major players and the contextual circumstances relevant to the creation of these treaties is concise but integral to an understanding of the negotiations leading to the production of the treaties, and their ultimate failure or success. This book is interesting as a historical treatment, but more importantly, imparts an understanding of the interplay of science, economics, public sentiment, and politics that is as relevant today as it was when these treaties were developed. I recommend it highly to anyone involved in conservation biology, diplomacy, legislation, and advocacy.

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Exploring Ecology and its Applications: Readings from American Scientist

Edited by Peter Kareiva. 1998. Sinauer Associates, Sunderland, Maryland. 277 pp., illus. U.S. \$24.95.

Magazines are too ephemeral. The covers are easily tattered and whole issues can be misplaced. In addition, there may only be one or two articles of interest in many issues. The editors of *American Scientist* have neatly solved this problem by gathering together a series of articles on ecology and publishing them in a single volume. The 27 articles in this book first appeared in the magazine from 1983-1997.

The articles are loosely gathered into four major categories. Part 1 tackles "The ecology of individuals: adaptations and strategies of organisms." Seven papers cover topics from mammalian hibernation to adaptive strategies of coral reef invertebrates. Part 2 covers issues related to "The dynamics and consequences of species interactions." Papers range from the emergence of new diseases to the ecology of a salt marsh. Part 3 addresses "Process and pattern in communities and ecosystems." Articles range from nonequilibrium determinants of community structure to the recovery of Spirit Lake after the eruption of Mount St Helens. Part 4 concludes with "Conservation and ecosystem

management." Issues such as the evolutionary potential of crop pests and biological invasions as global change are presented.

All the articles are written by ecologists who summarize their research for a non-specialist audience. Because of this approach, the reader gets both an introduction to a variety of specialized fields as well as insight into the tantalizing questions still facing ecologists. For example, I knew very little about honeybees and was amazed to discover that 75% of all new colonies in temperate environments perish during their first winter. Each article is filled with such fascinating tidbits and profusely illustrated with photos (most in colour), drawings, and graphs. For those who seek additional reading, each article also contains a reference list to primary literature. It is unlikely that anyone will be interested in every article in such a wide-ranging collection, but it is the sheer diversity of species and topics addressed that make this book so rewarding.

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The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice

Edited by David G. Victor, Kal Raustiala, and Eugene B. Skolnikoff. 1998. MIT Press, Cambridge, Massachusetts, xviii + 737 pp. U.S. \$27.50.

Regional concerns take on global significance when it comes to protecting the biodiversity which sustains the health of our natural ecosystems. Although this volume deals primarily with European efforts to reduce hazards to the environment, it will be of interest to anyone who is concerned about the spread of toxic pollutants and the welfare of species, which know nothing of international boundaries. Be prepared, however, for a long and tedious read. It took an act of will to get through the more than 737 pages of this book, 147 of which are comprised of footnotes. The use of acronyms is frustratingly prolific and there are no photographs or illustrations, only the occasional graph, table, and map. On the positive side, there are frequent summaries of the research findings throughout the volume. The book helped me to become more familiar with international agreements about which I have frequently heard. It also made me aware of the complex negotiations and procedures involved in establishing international agreements, as well as of the problems faced by

countries in transition from the old totalitarian Soviet regime to independent nationhood.

An anthology of articles by fourteen authors, the book is a report of a three-year research project. Examined are agreements to protect flora and fauna; to eliminate consumption of ozone-depleting substances; to reduce pollution of the atmosphere and oceans; to limit trade in hazardous chemicals and pesticides; and to stop whaling. There are two main sections. Part I focuses on systems for implementation review (SIRs). These are described as "institutions through which the parties share information, compare activities, review performance, handle non-compliance, and adjust commitments." Part II details how specific nations implement international environmental agreements to which they are signatories, with considerable attention given to Russia and to other Eastern European countries in transition to market-based economies.

The last chapter details the conclusions which include the following. Systems of implementation review clearly lead to more effective commitments. There is a trend toward greater openness and transparency in the development of policy, with non-governmental organizations having increased influence

on the implementation of agreements. Flexible non-binding agreements are more effective than those with enforcement measures, although there is a place for the latter. Where there is failure to meet international agreements it is due mainly to unanticipated factors rather than to intentional violation. The former Soviet republics have good records of compliance but this is due mainly to economic decline rather than to the effectiveness of the commitments. Such pressing issues as unemployment and crime have taken centre stage and environmental issues have been forced to the sidelines.

The chapter on the International Whaling Commission shows a definite pro-whaling bias,

which I think is unfortunate in a study of this kind. Roger Payne, a scientific advisor to the IWC, paints a very different picture in his book, *Among Whales* (Delta, New York, 1995).

The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice is not gift-book material. It has value, however, as a reference book with regard to international efforts to protect species and their habitats.

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The Living Dance: Policy and Practices for Biodiversity in Managed Forests

Edited by Fred L. Bunnell and Jacklyn F. Johnson. 1998.
UBC Press, Vancouver, xiv + 162 pp., illus.

This book is an edited collection of essays (scientific summary papers) about managing biological diversity in forests that resulted from yet another forest biodiversity workshop. Discussions pertaining to the management of biodiversity in forests are akin to Mark Twain's old adage about the weather: "everyone talks about it, but no one does anything about it". With the exception of two chapters (Noss' Chapter 7 on scale, and Bunnell's Chapter 8 on setting goals), most of this book is no different. There seems to be endless discussions here, and elsewhere, about definitions that have served only to cloud the issues further, and about the application of principles from agricultural landscapes that simply do not apply in forested systems. It is time to agree on some terms and definitions and to get on with it; part of the problem is too many people defining the same things in different ways followed by fruitless argument about who was precise and who was not. The failure by researchers to adequately articulate theories of biodiversity and to test these in the field is correctly pointed out in the preface. (Unfortunately, the preface is so bombastic that this and several other astute insights get lost in the rhetoric.) The tired old drum of "forest fragmentation" based on woodlots in agricultural systems is beaten again in Chapter 4. Meanwhile, tests in forested systems support the readily intuitive conclusion, that fragmentation is at worst ephemeral in forests. If there is a problem for vertebrates, it is more likely one of habitat loss and cumulative habitat loss. Landscapes need to be "connected" is another old chestnut from Chapter 4 — yet forest landscapes are always connected, at least by woody vegetation of some sort. The question in forests is not one of connectedness, but rather one of time and

space; habitat cannot remain the same forever and tree museums simply will not work over long time periods. Lest I seem overly critical of chapter 4 (and I really have no idea what the "biodiversity of populations" is), Dr. Merriam makes a wonderfully apt point on page 46, that current policy on biodiversity is inverted, driven by process rather than by science, and that science is now expected to "fill the policy".

The question of policy on biodiversity is addressed by Dr. Maini in Chapter 2, where he clearly illustrates the cart and horse objections raised later in Chapter 4. Monitoring is not a science question for example, and over-monitoring of keystone species in Canadian forests is hardly an issue. Dr. Maini notes that Canadian policy makers are faced with several key considerations (page 27); indeed these are important research issues, as are subsequent questions pertaining to the generality of the answers. His list is exhaustive however, and other important questions are formulated by Bunnell and Chan-McLeod in Chapter 1. Together, these provide a significant cut at a forest biodiversity research agenda for the next decade.

The significance of this book primarily lies in its final two chapters. In these synoptic essays the authors offer informed opinions, rather than hiding in the comfort of the "we don't know enough" paradigm. I was particularly impressed with Dr. Bunnell's succinct answers to the questions that he posed as a means to stimulate action. It appears that he, too, has had enough of the academically-interesting navel-gazing and is willing to move forward with the job at hand.

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Practical Approaches to the Conservation of Biological Diversity

Edited by Richard K. Baydack, Henry Campa III, and Jonathan B. Haufler. 1999. Island Press, Washington, D.C. xiv + 314 pp., illus., U.S.\$65.

In 1994, in response to the growing need to address various questions relating to biodiversity conservation, the Biological Diversity Working Group was formed within the Wildlife Society. This book is an expansion and refinement of the papers presented at the Second Annual Conference of the Wildlife Society in Portland, Oregon, in 1995. In general, the main aim of the book is to present strategies for the conservation of terrestrial biological diversity. The target readers are managers and students. The contents are meant to help the former select an appropriate technique and the latter to compare and contrast methods as a learning experience in various courses.

The 16 chapters of the book are divided into four parts. Part I is *Conserving Biodiversity – Principles and Perspectives*. Here we are introduced to the concept of biodiversity, its origin, why it is important, and current approaches to its conservation discussed at a general level. Part II consists of the strategies for conserving biodiversity. Each approach is described from theoretical perspective along with examples of practical case-study applications. Approaches are described in as many different ecosystems as possible in a wide range of locations. Part III is called *Opportunities and Challenges* and deals with common real-world constraints that trouble the enthusiasm for undertaking studies and management of biodiversity. Here the writing includes such chilling words and phrases as funding, fundamental, trivial, reliable knowledge, irrelevant, plethora of data, paucity of data, and shortage of time. Part IV is entitled *Summary and Recommendations* and attempts to outline a best course for the conservation of biodiversity and research needs for improved theory and management. The book concludes by proposing that it is possible and necessary to conserve biological biodiversity in virtually any management situation. Tell that to doctors fighting disease organisms or the forester spraying insecticide against Spruce Budworm.

The book is well worth reading and we are indebted to the editors and authors for the variety of views assembled between the covers. There are 26 contributors ranging from graduate students to professionals. The writing is clear with few mathematical formulae. For the determined there are some 750 references and most are in the 1990s. A good index helps one into the thickets of the text and gain an overview of features of the landscape of the book.

To someone familiar with the topic, other than checking what's new, I do not think they will gain a great deal from the book that they did not know or

suspect. To the novice, the book touches on or explains most of the key words that define biodiversity and its management (e.g., alpha diversity and HRV or historical range of variability).

The authors deserve our thanks and congratulations for addressing a fundamental issue and making headway with the huge and difficult problem of understanding and managing biodiversity. Basically, this is the conservation of life. And the book begins to show the breadth of vision required to undertake and solve the problem and do the correct thing about it. As examples, consequences of pollution and exotic species are at the global level, and ecosystems reflect environmental limits not political boundaries. Here and now, the Forest Management Plan for Lanark County by The O.M.N.R. deals only with public land. The surrounding land is privately owned and ignored. According to the beliefs of biodiversity this may result in species loss.

So what would you have done with this topic? The book probably shows us where we are in the field, hence the word approaches in the title. In this case the approaches show we have directions to take but are far off in actually getting there. As Campa III, Baydeck and Haufler say (page 251): "All the approaches discussed in this book are hypotheses about how to conserve biological diversity and, as such, need to be evaluated." Amen, and while biodiversity is almost intuitively a good thing, please give data on what it is, and how it is organized and functions. Where are the analyses of the biological, social, and economic costs and benefits of biodiversity? Without such information how can we convince people and politicians of the consequences we face? Other than the impact of exotic species, particularly on island populations, what is the evidence that large ecosystems may fall apart with a change in biodiversity? For example, native American Chestnut and White Elm, once major components of the forests of southern Ontario are virtually eliminated by exotic diseases. Yet the vast majority of other species carry on within HRV and some may even be enhanced by the elimination of competition. In my view, a fundamental component of ecosystems is their sustainability and biodiversity must be linked to the capacity of land and water to be sustained. Yet sustainability does not even appear in the index!

Another addition might be a broader view of ecosystems and a greater explanation of their structure and function. Perhaps reflecting the interests of the authors, vertebrates receive much attention. Yet biodiversity is made mostly of bacteria, fungi, plants, and invertebrates. Moreover, ecosystem function must depend heavily on these components. They deserve much more attention. The excuse of the authors is we cannot deal with everything. Probably true and information is needed on what and how

major organisms function in ecosystems.

As usual, the dogma that habitat produces wildlife is accepted, and many schemes for the classification of habitat for the production of biodiversity are proposed. Managers manipulate habitat and assume wildlife responds. Hopefully, adaptive management, or learning by doing, will help us find the desired result. At present, we have little knowledge of exactly what elements of habitat various species require. Moreover, the habitat approach, while needed, ignores the variability within species as to habitat requirements. In Spruce and Blue grouse for example, the needs of the hen for reproduction seem crucial to abundance. What are these needs? They may include microclimate for eggs, foods to the hen and the very young chicks, and freedom from predation. On Vancouver Island, Blue Grouse may become extremely abundant on the lowland after logging where none lived before. This lowland habitat and grouse quickly disappear with the regrowth of forest. Throughout this time and beyond, the species lives at low density in the subalpine forest. Clearly, there is a lowland and subalpine type of Blue Grouse and different habitats may be needed by each for the persistence of the one species.

Many other questions of habitat are raised by the book but few answers given. For example, how

much area and where is it required to preserve biodiversity? With so little of our land dedicated to preservation it seems obvious the answer must involve the cooperation of private landowners. Heavy dependence on our few National and Provincial parks may weaken the involvement with private lands. And what units of habitat will produce the desired species? Huge vegetation zones such as the boreal forest through a few square meters of water from a spring? Surely the units will not be as broad as dry forest and wet forest, and then to consider arctic vegetation and boreal forest as dry (page 173)!

Where there are some actual numbers in the book, the correlation between habitat and the abundance of a species is not comforting. We all know wetlands produce waterfowl. However, I graph a poor or no correlation between ponds/km² and breeders/km² of Mallards in the year or year after from 1971 through 1990 (page 149).

We want and need biodiversity. In my view, the basic measure of biodiversity is the distribution and abundance of species and their value.

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MISCELLANEOUS

The Platypus and the Mermaid and Other Figments of the Classifying Imagination

By Harriet Ritvo. 1998. Harvard University Press, Cambridge, Massachusetts. xiv + 288 pp., illus. U.S.\$15.95.

"What is in a name?" a casual observer might ponder. Why such energy and time pigeon-holing nature, past and present, into our own perceptions of nature? Or, who cares how many species are going extinct, isn't it enough that they are in danger of sharing the same museum cabinet as that of the Dodo? Harriet Ritvo's *The Platypus and the Mermaid* illustrates the historical placement of nature into the human construct of systematic boxes. The purposes of identifying species today is much different than it was in the 19th century and before, and it was the extremes of nature, natural and unnatural, that tested the metal of many taxonomists, and in some cases even the public.

As one would expect, the early portion of this book focuses on the development of classification, specifically that of the Linnean system. Other attempts at trinomial pigeon-holing of nature are also discussed, along with more eccentric attempts like "Quinary circles" which emerged in the early 19th century. This was an "attempt to represent the

complex, overlapping sets of resemblances among animals" (page 31) as circles, touching each other at like physiological points. This two dimensional approach caused all sorts of confusion to which one of the many observers, Charles Darwin, was more than happy to see fall by the way side.

The apparent anomalies of nature, like the kangaroo and platypus in the 19th century, caused some confusion, each having external features unrelated to their basic make-up. Taxidermic alterations were soon ruled out, in the case of the platypus, as more specimens were brought to the attention of the learned but its "weirdness" continued on. But it was much closer to home that non-academics voiced their own classificatory discern as breeders of domestic animals (whether for food or pet) were in want of some professional assistance. Each breed was in want of distinction from the others, and hybrids were frowned upon as each version of the parents would lose "its original perfection", as Ritvo quotes one observer.

But varieties in the animal world were not the only concern for early taxonomists, and it was with the varieties of human kind and, to use a pre-20th

century term, "monstrosities" that invited the most discussion. "[W]hen the subjects under discussion were human - when the relationship between zoological and social categories appeared still closer - the temperature of discussion tended to rise again" (page 120). The linear concept of nature held by many, including many 19th century evolutionists, caused rankings of animal and human types; one was better than the other. And when it came to races, these were often, as would be expected, based on "the political perspective of the observer" (page 127).

A sizable portion of *The Platypus and the Mermaid* draws from the abnormal (for want of a better word) appearances found in nature. Commonly referred to as "monsters" these creatures and souls provided much interest to the pre-20th century academics and public. The "Irish Giant", for example, advertised as being 8 and a half feet tall,

fascinated all. Though even in death the towering Charles Byrne could not rest. Despite his protestations in life, and attempts to sink his body after death into the Irish Channel, the giant's bones were procured, boiled, and placed on museum exhibition.

We seek to understand nature by placing it in our own shoe box of limited knowledge. Ritvo at times bludgeons the point with examples, illustrating nonetheless, that as our exploration of nature and ourselves expands, the purpose of the shoe box also changes. The early stumblings of science may have been honorable, even with a higher purpose, but they were also, with the advantage of a 20th century perspective, rather wretched at times. This is our history.

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NEW TITLES

Zoology

The Alex studies: cognitive and communicative abilities of grey parrots. 1999. By I. M. Pepperberg. Harvard University Press, Cambridge. 448 pp., illus. U.S. \$39.95.

Atlas of Oregon wildlife. 1999. By B. Csuti, A. J. Kimerling, T. A. O'Neil, M. M. Slaughnessy, E. Gaines, and M. Huso. Oregon State University Press, Corvallis. 480 pp., illus. U.S. \$39.95.

†**Distribution, survival, and numbers of lesser snow geese of the western Canadian Arctic and Wrangel Island, Russia.** 1999. Edited by R. H. Kerbes, K. M. Meeres, and J. E. Hines. Occasional Paper No. 98. Canadian Wildlife Service, Ottawa. 118 pp., illus.

†**The encyclopedia of sharks.** 1999. By S. and J. Parker. Firefly Books, Willowdale, Ontario. 192 pp., illus. \$24.95.

Hierarchy in the forest: the evolution of egalitarian behavior. 1999. By C. Boehm. Harvard University Press, Cambridge. 320 pp. U.S. \$39.95.

†**Hoofed mammals of British Columbia.** 1999. By D. Shackleton. University British Columbia Press, Vancouver. 176 pp., illus. \$24.95.

If a lion could talk: animal intelligence and the evolution of consciousness. 1998. By S. Budiansky. Free Press, New York. xxv + 219 pp., illus. U.S. \$25.

†**Mammals of Madagascar.** 1999. By N. Garbutt. Yale University Press, New Haven. 320 pp., illus. U.S. \$37.50.

†**Mammals of North America: temperate and arctic regions.** 1999. By A. Forsyth. Firefly Books, Willowdale, Ontario. 352 pp., illus. \$40.

†**The miracle of flight.** 1999. By. S. Dalton. Firefly Books, Willowdale, Ontario. 184 pp., illus. \$40.

†**The nature of hummingbirds: rainbows on wings.** 1999. By H. Thurston. Greystone Books, Douglas and McIntyre, Vancouver. 128 pp., illus. \$34.95.

***A practical guide to vertebrate mechanics.** 1999. By C. McGowan. Cambridge University Press, New York. xiii + 301 pp., illus. U.S. \$39.95.

Rare amphibians, reptiles, and mammals of British Columbia. 1999. By S. G. Cannington, L. R. Ramsay, D. F. Fraser, and M. A. Fraker. Crown Publications, Victoria. 400 pp.

Rare birds of British Columbia. 1999. By W. L. Harper, D. F. Fraser, S. G. Cannings, and J. M. Cooper. Crown Publications, Victoria. 400 pp.

†**Research and management of the brown-headed cowbird in western landscapes.** 1999. By M. L. Morrison, L. S. Hall, S. K. Robinson, S. I. Rothstein, D. C. Hahn, and T. D. Rich. Cooper Ornithological Society, Camarillo, California. ix + 312 pp., illus. U. S. \$18.

†**Ringed seals in the north Atlantic.** 1998. Edited by M. P. Heide-Jorgensen and C. Lydersen. Nammco Scientific Publications, Tromsø, Norway. 273 pp., illus. NOK 350.

The Science Times book of mammals. 1999. Edited by N. Wade. Lyons Press (Canadian distributor Fitzhenry and Whiteside, Markham, Ontario) 288 pp., illus. \$38.

The search for the giant squid. 1998. By R. Ellis. Lyons Press, New York. xi + 322 pp., illus. U.S. \$35.

The shark almanac: a complete look at a magnificent and misunderstood creature. 1999. By T. B. Allen. Lyons Press (Canadian distributor Fitzhenry and Whiteside, Markham, Ontario) 336 pp., illus. \$53.

Silent thunder: in the presence of elephants. 1998. By K. Payne. Simon and Schuster, New York. 288 pp., illus. U.S. \$25.

†**The Smithsonian book of North American mammals.** 1999. Edited by D. E. Wilson and S. Ruff. Smithsonian Institution Press (distributed in Canada by University of British Columbia Press, Vancouver) 816 pp., illus. \$95.

***Snake: the essential visual guide to the world of snakes.** 1999. By C. Mattison. Firefly Books, Willowdale, Ontario. 192 pp., illus. \$39.95.

†**Transients: mammal-hunting killer whales of British Columbia, Washington, and southeastern Alaska.** 1999. By J. K. B. Ford and G. M. Ellis. University of British Columbia Press (distributed by Raincoast, Vancouver). 96 pp., illus. \$24.95.

The whale watcher's handbook. 1999. By D. Bulloch. Lyons Press (Canadian distributor, Fitzhenry and Whiteside, Markham, Ontario). 128 pp., illus. \$22.95.

***Wild birds across the prairies.** 1999. By W. Lynch. Fifth House, Calgary. 138 pp., illus. \$18.95.

Botany

†**An enthusiasts guide to the liverworts and hornworts of Ontario.** 1999. By L. M. Ley and J. M. Crowe. Claude Garton Herbarium, Lakehead University, Thunder Bay. vii + 134 pp., illus. \$15.

†**Forests to fight poverty.** 1999. Edited by R. Schmidt, J. K. Berry, and J. C. Gordon. Yale University Press, New Haven. ix + 198 pp., illus. Cloth U.S. \$30; paper U.S. \$15.

Flora of Mount Rainier National Park. 1999. By D. Biek. Oregon State University Press, Corvallis. 488 pp., illus. U.S. \$29.95.

Flora of Steens Mountain. 1999. By D. H. Mansfield. Oregon State University Press, Corvallis. 425 pp., illus. U.S. \$29.95.

***A guide to the ferns of Grey and Bruce Counties, Ontario.** 1999. By the Bruce-Grey Plant Committee. Stan Brown Printers, Owen Sound, Ontario.

***Illustrated flora of British Columbia, volume 3: Dicotyledons (Diapensiaceae through Onagraceae).** 1999. Edited by G. W. Douglas, D. Neidinger, and T. Pojar. B.C. Ministry of Environment, Lands, and Parks, Victoria.

Paramos: a checklist of plant diversity, geographical distribution, and botanical literature. 1999. By J. L. Luteyn. New York Botanical Garden Press, Bronx. U.S. \$84.

Phytogeography: the history and formation of species. 1999. By J. C. Avise. Harvard University Press, Cambridge. 384 pp., illus. U. S. \$49.95.

Plants of the Oregon coastal dunes. 1999. By A. M. Wiedemann, L. R. J. Dennis, and F. H. Smith. New Edition. Oregon State University Press, Corvallis. 128 pp., illus. U.S. \$12.95.

Roland's flora of Nova Scotia. 1998. Revised by M. Zinck. Nimbus Publishing, Halifax. 2 volumes. \$70.

†**Spatial pattern analysis in plant ecology.** 1999. By M. R. T. Dale. Cambridge University Press, New York. x + 326 pp., illus. U.S. \$69.95.

Symmorphosis: on form and function in shaping life. 1999. By E. R. Weibel. Harvard University Press, Cambridge. 256 pp., illus. U.S. \$45.

Trees of the pacific northwest. 1999. By G. A. Petrides and O. Petrides. Explorer Press (Canadian distributor Fitzhenry and Whiteside, Markham, Ontario). 104 pp., illus. \$19.95.

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Environment

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(continued on inside back cover)

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Cover: Male Harlequin Ducks, *Histrionicus histrionicus*, loafing on a mid-channel boulder, Quartzville Creek, Linn County, Oregon, USA, April 1995. Photographed by Robert Jarvis, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon. See: The distribution, phenology, and prey of Harlequin Ducks, *Histrionicus histrionicus*, in a Cascade Mountain stream, Oregon, pages 187-195.

The Distribution, Phenology, and Prey of Harlequin Ducks, *Histrionicus histrionicus*, in a Cascade Mountain Stream, Oregon

KRISTOPHER K. WRIGHT^{1,2}, HOWARD BRUNER¹, JUDITH L. LI¹, ROBERT JARVIS¹, and STEVE DOWLAN³

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Wright, Kristopher K., Howard Bruner, Judith L. Li, Robert Jarvis, and Steve Dowlan. 2000. The distribution, phenology, and prey of Harlequin Ducks, *Histrionicus histrionicus*, in a Cascade Mountain stream, Oregon. Canadian Field-Naturalist 114(2): 187–195.

We examined the phenology, abundance, and in-stream habitat use of Harlequin Ducks (*Histrionicus histrionicus*) and their primary prey, the caddisfly larvae *Dicosmoecus gilvipes*, in a Cascade Mountain stream from 1994–1997. Harlequins and *D. gilvipes* inhabited the stream from late April through late July, and both frequented areas with high proportions of bedrock. When broods were present in late June and July, *D. gilvipes* made up over 80% of harlequin diets. Although harlequins foraged intensively on *D. gilvipes*, we found no direct relationship between harlequin distribution and caddisfly abundance at nine 50 m study sites. After a severe flood in early 1996, we observed reductions in overall harlequin numbers, a seasonal delay in brood development, and a decrease in abundance of *D. gilvipes*.

Key Words: Harlequin Ducks, *Histrionicus histrionicus*, caddisfly, *Dicosmoecus gilvipes*, phenology, distribution, predator-prey relationships, streams, brooding, Cascade Mountains, Oregon.

Harlequin Ducks (*Histrionicus histrionicus*), or harlequins, are Holarctic sea ducks that reproduce along high-gradient streams in tundra and forest systems, nest within riparian areas, and over-winter in coastal tidal zones (e.g., Bellrose 1976; Bruner 1997; Cassirer and Groves 1991*; Hunt 1998; MacCallum 1997*; Palmer 1976; Robertson 1997; Smith 1996*; Wallen 1987). Movement of Harlequin Ducks to streams from coastal wintering areas occurs in early spring, with males returning to marine environments prior to female incubation. Females remain on the streams until their young fledge in late summer. Despite this apparent dependence of Harlequin Ducks on streams, there is limited information on the phenology, in-stream habitat use, and diet of breeding harlequins.

In coastal wintering habitats, harlequins feed on a variety of macroinvertebrates and fish eggs by diving in the shallow surf (Bengtson 1972; Dzinbal and Jarvis 1984; Fischer 1998; Gaines and Fitzner 1987; Goudie and Ankney 1986; Goudie and Ryan 1991; Vermeer 1983). In summer habitats, breeding ducks generally consume aquatic insects and may forage on either specific taxa (e.g., Simuliidae) or a wide range of species (Bengtson and Ulfstrand 1971;

Cassirer and Groves 1991*, 1992*, 1994*; Farrell 1997; Gardarsson and Einarsson 1994; Rodway 1998). In Iceland, abundance of aquatic insects appeared to influence both distribution and reproductive effort (Bengtson and Ulfstrand 1971; Gardarsson and Einarsson 1994); however, in Idaho and Washington occurrence of Harlequin Ducks was not related to abundance of total stream invertebrates (Cassirer and Groves 1994*; Farrell 1997).

At Quartzville Creek, a fifth-order stream in the Oregon Cascade Range, we observed harlequin females and broods feeding on aquatic insects, primarily the limnephilid caddisfly *Dicosmoecus gilvipes*. *Dicosmoecus* can dominate stream macroinvertebrate biomass (Tait et al. 1994), and be an important component of stream assemblages (Power et al. 1995; Wootton et al. 1996). Stone-cased *D. gilvipes* larvae may be inaccessible to stream-dwelling predators such as fish (Power et al. 1995; Wootton et al. 1996), but their role is more integral when stream food-webs are expanded to include birds such as Harlequin Ducks and Dippers (*Cinclus mexicanus*) (Harvey and Marti 1993; Mitchell 1968; Thut 1970; Wright 1997).

The purpose of this study was to examine the temporal and spatial patterns of Harlequin Ducks and their stream prey in Quartzville Creek in 1994–1997. Primary objectives of our study were: (1) determine

*See Documents Cited section.

the phenology, abundance, in-stream habitat use, and diet of harlequins in Quartzville Creek, and (2) examine the phenology and distribution of the prey species *D. gilvipes* in Quartzville Creek. In February 1996, flooding on Quartzville Creek caused extensive channel-bed movement and riparian scour. Severe floods can restructure the composition and distribution of riparian and stream communities (e.g., Lamberti et al. 1991; Poff and Ward 1989; Power et al. 1988; Resh et al. 1988; Wootton et al. 1996). *Dicosmoecus gilvipes*, in particular, has been shown to be susceptible to severe flooding events (Wootton et al. 1996; Wright 1997; Wright and Li 1998). Therefore, this event provided an opportunity to examine the potential impacts of a severe disturbance on Harlequin Ducks and their prey. We hypothesized that prey availability in Quartzville Creek and harlequin production would be reduced following the 1996 flood.

Methods

Study Area

Quartzville Creek in Linn County, Oregon, USA (44° 30'N, 122° 25'W), is a tributary of the Middle Fork of the Santiam River in the western slopes of the Cascade Range. Quartzville Creek is a fifth-order stream, with a mean summer discharge between 1.67 and 2.83 cubic meters per second (Eccles and Graves 1992*). Dominant woody vegetation includes *Pseudotsuga menziesii*, *Thuja plicata*, *Tsuga heterophylla*, *Alnus rubra*, *Acer macrophyllum*, *Acer circinatum* and *Salix* species. The stream bed is composed of approximately 40% bedrock, 35% cobble, 10% boulder, and 15% fines (Wright 1997). Ownership within the watershed is a patchwork of private timber companies and federal agencies. Quartzville Creek provides a variety of outdoor recreational activities including gold mining, camping, fishing, and viewing wildlife.

Harlequin Ducks

In North America, Harlequin Ducks are more numerous on the Pacific Coast than on the Atlantic Coast, and abundance decreases from north to south (Bellrose 1976; Palmer 1976). Currently, harlequins are known to breed only as far south as central Oregon and northern Wyoming, U.S.A. In Oregon, most birds breed on the west slope of the Cascade Mountains; dependence on forested/montane riparian canyons makes them vulnerable to both natural and anthropogenic disturbances (Bruner 1997). Density of breeding harlequins in these streams varies from <0.5 to 3 pairs per river km. Harlequin Ducks are listed as a species of concern in Oregon by the U.S. Fish and Wildlife Service, and a species of undetermined status by the Oregon Department of Fish and Wildlife (Latta 1993). According to U.S. Bureau of Land Management surveys, the largest breeding population in Oregon occurs on Quartzville Creek, a

U.S. National Wild and Scenic River (Dowlan 1996).

In 1994–1997, extensive, single-day harlequin surveys were conducted along a 15 km segment of Quartzville Creek in late spring and mid-summer (see Dowlan 1996). Additional surveys along 4 km of the 15 km were conducted periodically throughout the four summers. Duck location, sex, numbers present, age class of ducklings and habitat type were recorded with each sighting. In 1995–1997, harlequin broods and adult females were captured by mist-netting and banded in late summer. Banding in late summer focused solely on broods that were ready to fledge (Class IIC and III; Gollop and Marshall 1954).

To examine temporal and spatial associations between harlequins, in-stream habitat, and macroinvertebrates, this study focused on nine sites, each 50 m in river length, along a 2.5 km stretch of Quartzville Creek. In 1995 and 1996, visual observations of Harlequin Ducks within the study sites were recorded before and during invertebrate sampling on all sample dates. For each Harlequin Duck observation at each site we recorded: (1) location, (2) number of ducks, (3) sex, (4) number of ducklings present, (5) time of sighting, (6) behavior, and (7) local habitat characteristics. For this portion of the study, we did not distinguish individual ducks nor did we note repeated observations of the same individual.

Relationships between harlequin distribution and in-stream habitat were established by comparing number of duck observations and physical habitat characteristics at each site. In-stream habitat type, substrate size, and average water depth at each site were determined when caddisflies were counted. Habitats were classified as riffle, glide (run), pool, backwater, and edge habitat. Substrates were classified as bedrock, large boulder, small boulder, cobble, gravel, sand and silt, based on modifications of definitions in Wentworth (1922). In 1995, mean site stream velocity was measured monthly using a digital flow meter held 2.5 cm off the stream bottom at ten random locations within each site.

Macroinvertebrates

Stream macroinvertebrates were sampled from mid-May through July to coincide with the presence of larval caddisflies and Harlequin Duck residency. In 1995–1997, *D. gilvipes* were counted visually using a 0.1 m² water scope (Li 1990; Wright and Li 1998). The water scope is most appropriate for counting *D. gilvipes* because: (1) these caddisflies are large (> 1.5 cm), (2) they forage atop large and small substrates, and (3) other methods typically under-estimate *D. gilvipes* densities (Li 1990; Mackay and Wiggins 1979; Wright 1997; Wright and Li 1998). Visual observations were made mid-day when *D. gilvipes* were most active. Four transects perpendicular to shore, extending the wetted channel width, were chosen randomly for each sam-

ple date within each of the nine 50 m sites. Numbers of individuals/instar were counted at 1 m intervals along each transect. Caddisfly species were verified, from collected samples stored in 95% ethanol, with a $10\times - 40\times$ dissecting microscope. Maturation of *D. gilvipes* was determined by seasonal changes in larval size and case morphology, and verified in the lab with samples of each instar.

To enumerate other components of the macroinvertebrate community, benthic samples were taken monthly during May, June, and July of 1995 and 1996. Six randomly selected samples were taken at each site, using a (0.12 m^2) modified Surber sampler with a $250\text{ }\mu\text{m}$ mesh net. Substrates were stirred for 30 seconds to a depth of 10 cm where possible. Samples were sieved through a $250\text{ }\mu\text{m}$ screen and preserved in 95% ethanol. Each sample was counted and invertebrates identified to genus in the laboratory.

Harlequin Diet

Harlequin diet was determined by examining a total of 33 fecal clusters in 1995 and 1997. Ten feces were collected 11 July 1995 by following an adult female with five ducklings as they moved throughout the study area. The ducks fed for a short time before hauling out on rocks to defecate, preen and rest. The remaining six 1995 samples were collected in late June and July from locations repeatedly used by harlequins to rest after feeding. In 1997, 17 fecal samples were collected in May, June and July from loafing sites frequently used by Harlequin Ducks. Contents were identified by inspection of undigested macroinvertebrate body parts under a dissecting microscope ($25\times$). Percent estimates of diet content were made by visual inspection under a dissecting microscope using a partitioned dish. Diet from fecal samples may underestimate consumption of soft-bodied organisms; however, head capsules of larval and adult stream insects were intact.

Analyses

Analysis of variance (ANOVA) was used to compare average densities of macroinvertebrates among years. Regression was used to examine relationships between harlequin observations and (1) estimated benthic invertebrate densities, (2) proportions of habitats and substrates, (3) average depth, and (4) stream velocity, at all sites. Statistical significance was indicated at the 95% (p -values < 0.05) confidence level.

Foraging electivity of harlequins in 1995 was calculated by comparing diet content and prey availability (Ivlev 1961). Prey availability was determined by averaging densities of *D. gilvipes*, Ephemeroptera and Plecoptera, other Trichoptera, Diptera, Coleoptera, Odonata, Megaloptera, and non-insects from the nine study sites in 1995. Electivity for each invertebrate taxon was determined for each of 16 fecal samples; the Ivlev electivity of each taxon was then averaged

for all 16 fecal samples. Electivity was limited to 1995 because abundance of total macroinvertebrates was not measured in 1997, and fecal samples were not collected in 1996.

Results

Harlequin Ducks

Phenologies of harlequin spring activities were consistent from 1994-1997. Harlequins began arriving at Quartzville Creek in April; duration of the males' residence was 6-7 weeks. Though broods in 1994, 1995, and 1997 were recorded within the third week of June, first broods in 1996 were recorded 2-3 weeks later in the season (Figure 1). In 1995 and 1997, the majority of broods developed to Class IIC and III and were banded in late July and early August, but 1996 ducklings were too young for banding until 15 August.

Total number of ducks observed in the 1994-1997 spring surveys ranged from 35 to 15 (Table 1), and were lower in 1996 and 1997 than 1994 and 1995. Summer surveys revealed that numbers of individuals and broods were reduced in 1996 compared to other years (Table 1). Whereas we observed 6-8 broods in summers of 1994, 1995 and 1997, in summer 1996 we observed only two broods (Table 1). Of the three females observed in summer 1996, two banded individuals had returned to Quartzville Creek from the previous year. We observed the highest number of ducks in 1997 when we counted eight broods, totaling 51 ducklings.

In a comparison between sites, percent bedrock was the only in-stream physical characteristic significantly related to in-stream harlequin observations in 1995 and 1996 ($p = 0.008$, $r^2 = 0.32$) (Figure 2). Despite localized changes in the amount of bedrock substrate following the flood, there was no significant difference between years in the overall availability of bedrock throughout the study area (Wright 1997).

Fecal analyses from 1995 and 1997 verified our initial observations that harlequins forage heavily on *D. gilvipes*. Of the 16 samples in 1995, 12 contained 100% *D. gilvipes* material and the remaining four samples contained more than 85% *D. gilvipes* material; some mayflies (Ephemeroptera) and stoneflies (Plecoptera) also were consumed. In 1997, *D. gilvipes* was again a major component of harlequin diet, beginning in mid-June (Table 2). Average electivity for *D. gilvipes* was positive (Ivlev's index = 0.92, $n = 16$), and negative for all other invertebrates (Ivlev's indices < -0.05 , $n = 16$). In June 1996 we also observed a female harlequin in Quartzville Creek ingest fish; this behavior had not been previously recorded.

Macroinvertebrates

In Quartzville Creek, first instar *D. gilvipes* larvae over-winter until March-April when they begin more rapid maturation. In 1995 and 1997, *D. gilvipes*

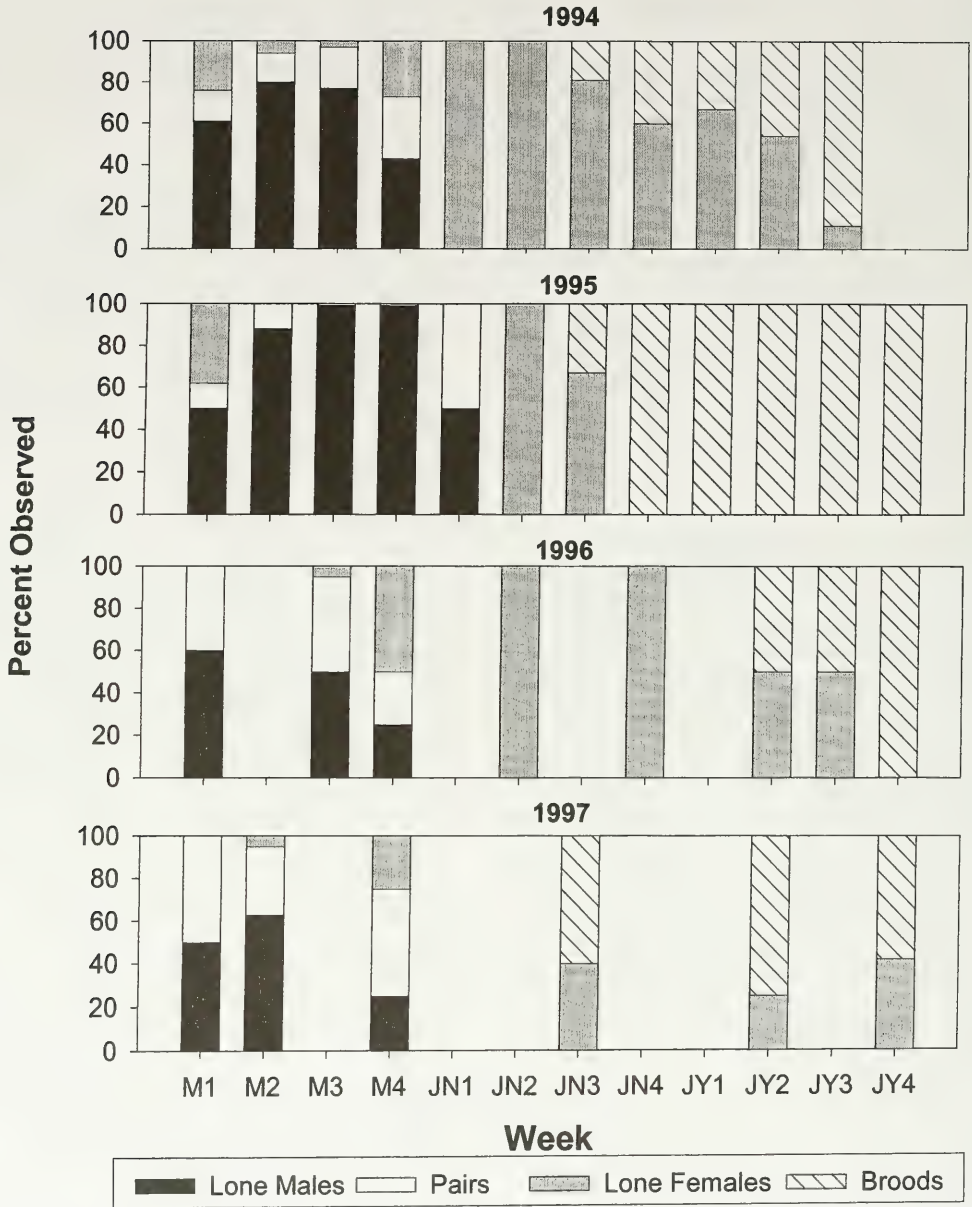


FIGURE 1. Proportion of Harlequin Duck observations according to lone males, pairs, lone females, and broods for each week in the summers of 1994–1997. Months are abbreviated as M, JN, and JY for May, June, and July respectively. Blank cells represent weeks without survey data.

developed from second to third instars in early May, from third to fourth instars in late June, and from fourth to fifth instars in mid to late July (Figure 3). The final (fifth) instars typically entered prepupation in late July, by sealing themselves to the underside of rocks. Following the flood in February 1996, instar transitions were 2–3 weeks later than in 1995 and 1997 (Figure 3). The majority of *D. gilvipes*

from all years were found on bedrock (Table 3).

Dicosmoecus gilvipes densities were significantly higher in 1995 than in either 1996 or 1997 following the flood (Table 4). There were no significant differences among caddisfly instar densities within either 1995 or 1996; densities in 1997 declined steadily beginning with third instars (Figure 4). Annual densities of all benthic macroinvertebrates were not sig-

TABLE 1. Spring and summer census of Harlequin Ducks on Quartzville Creek, Oregon, 1994–1997. Surveys were conducted along 15 km of stream; observations included 4 km surveys and mist-netting attempts. Totals included all pairs, individuals, and ducklings.

Year	Spring Surveys		Summer Surveys		Summer Observations Broods
	Pairs	Total	Broods	Total	
1994	9	35	4	20	6
1995	12	32	4	25	7
1996	7	19	2	11	2
1997	6	15	8	51	8

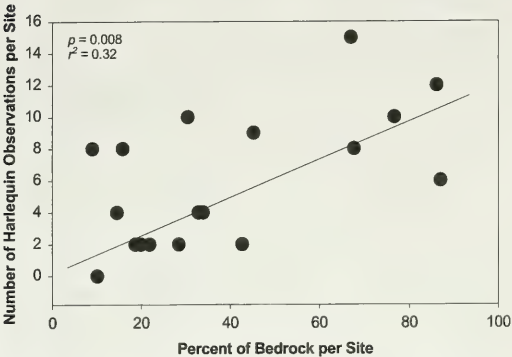


FIGURE 2. Relationship between the number of Harlequin Duck observations and the percent of bedrock at each site in 1995 and 1996 in Quartzville Creek, Oregon.

nificantly different between 1995 and 1996 (Table 4). Though densities of total benthic invertebrates in May and June 1996 were substantially lower than in 1995, abundances reached comparable levels by July (Figure 5). Total annual densities of EPT taxa were significantly lower in 1996 than in 1995 (Table 4).

Harlequin Ducks and Macroinvertebrates

Numbers of duck observations, within each study site, were compared to mean densities of *D. gilvipes*, total benthic invertebrate taxa and EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa (see Wright 1997). These inter-site comparisons revealed no significant relationships between annual numbers

of harlequins and either annual estimated means of *D. gilvipes*, total benthic invertebrates, or EPT taxa densities ($p = 0.24, 0.051$ and $0.08, r^2 = 0.03, 0.19$ and 0.13 respectively) at each site. However, both ducks and caddisflies frequented areas with high proportions of bedrock (Figure 2, Table 3)

Temporal overlaps between harlequins and *D. gilvipes* were established by qualitatively comparing harlequin arrival at Quartzville Creek, presence of males, and brood development to *D. gilvipes* instar maturation. Ducks arrived, paired, and copulated throughout May when *D. gilvipes* were developing from second to third instars (Figures 1 and 3). Larger-bodied fourth and fifth instars of *D. gilvipes* were available in late June and July when broods were being reared. Finally, harlequin broods fledged late in the summer, leaving the stream at the same time fifth instar *D. gilvipes* were beginning to pupate.

Discussion

In this study Harlequins foraged primarily on the large-bodied caddisfly *Dicosmoecus gilvipes* in June and July, during brood development. Fecal analysis indicated positive electivity for *D. gilvipes* by Harlequin Ducks, and both species frequented bedrock dominated areas, but no significant site-specific spatial associations were detected. However, there was suggestive evidence of temporal associations between Harlequin Ducks and *D. gilvipes*.

The use of bedrock by both harlequins and *D. gilvipes* may suggest an indirect spatial association between predator and prey. Harlequins appeared to be

TABLE 2. Estimated volumetric composition breakdown of harlequin fecal samples from 1997 in Quartzville, Oregon (n = number of fecal clusters examined).

Date	<i>Dicosmoecus</i>	Other Trichoptera	Ephemeroptera & Plecoptera	Diptera
8 May (n = 2)	0%	83%	17%	0%
22 May (n = 4)	0%	71%	29%	0%
21 June (n = 4)	45%	33%	18%	4%
10 July (n = 4)	86%	4%	10%	0%
24 July (n = 3)	69%	0%	25%	6%

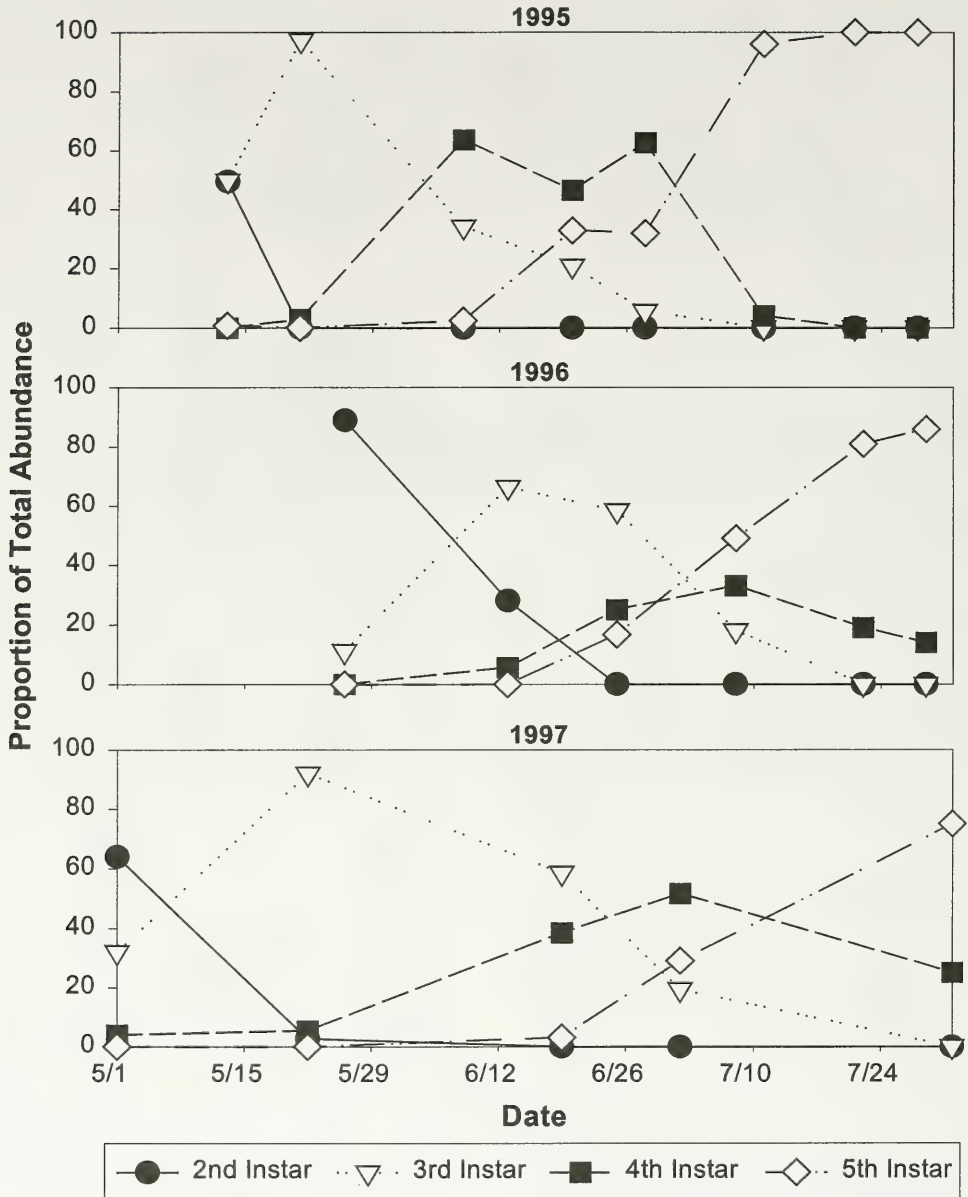


FIGURE 3. Percent of sampled *Dicosmoecus gilvipes* 2nd, 3rd, 4th, and 5th instars on each sample date in 1995, 1996, and 1997 in Quartzville Creek, Oregon.

selecting bedrock as foraging areas; this preference may have been based on a variety of physical characteristics or local prey abundance. At the site scale, harlequin distribution did not appear to be determined by food availability; they were not significantly related to densities of *D. gilvipes*, total benthics, or EPT taxa. Therefore, it appeared that harlequins in Quartzville Creek selected foraging areas based on stream hydrology and substrate characteristics. Ducks

may prefer bedrock because of: (1) relatively laminar flow increasing visibility, (2) light coloration providing a contrast to detect prey, particularly cases of *D. gilvipes*, (3) absence of finer particulates resulting in more efficient feeding, and (4) lack of substrate complexity reducing invertebrate refuges. *Dicosmoecus gilvipes* may prefer bedrock because algae are readily accessible and abundant in open-canopied systems (Tait et al. 1994). In addition, swift laminar flow

TABLE 3. Proportions of counted *Dicosmoecus gilvipes* according to substrate type in Quartzville Creek, Oregon, in 1995, 1996, and 1997 (n = total number of observations made in each year).

Year	Bedrock	Large Boulder	Small Boulder	Cobble	Gravel	Sand	Silt
1995 (n = 2591)	47.2%	0%	12.0%	26.2%	3.5%	9.3%	1.7%
1996 (n = 372)	60.5%	3.0%	2.4%	23.7%	8.9%	1.6%	0%
1997 (n = 272)	60.8%	5.1%	9.6%	17.6%	3.6%	3.2%	0%

TABLE 4. Average densities (#/m²) (±1 SD) of *Dicosmoecus gilvipes*, total benthic macroinvertebrates, and EPT (Ephemeroptera, Plecoptera, and Trichoptera) taxa from 1995–1997 in Quartzville Creek, Oregon.

Year	<i>D. gilvipes</i>	Total Benthic Invertebrates	EPT taxa
1995	19.3 (10.0)*	482 (53)	237 (52)*
1996	2.8 (0.5)	308 (96)	106 (11)
1997	2.9 (1.2)		

* indicates a significant difference between years at the 0.05 level.

associated with bedrock may be unfavorable to smaller herbivores, reducing potential competition for large caddisflies (Lamberti et al. 1995; Li and Gregory 1989). The shallow habitat created by bedrock glides also may be unfavorable to fish large enough to eat *D. gilvipes*, but these appear to be optimal foraging sites for insectivorous birds.

At the temporal scale, our results suggested that Harlequin Ducks switched preferred prey items in late June when: (1) harlequin broods were generally

first observed, and (2) *D. gilvipes* were developing from third to larger-bodied fourth instar. Other studies have recognized that invertebrates are crucial in the diets of ducklings (e.g., Baldassarre and Bolen 1994). In fact, hatching peaks for ducks often coincide with periods when invertebrates are especially abundant (Baldassarre and Bolen 1994; Bartonek and Hickey 1969). The favored prey of harlequins in our study, *D. gilvipes* as late instars, is approximately an order of magnitude greater in lipid content than other available benthic invertebrates (Hanson 1983). Timing of instar development and high nutritional value of these caddisflies makes them a valuable energy source to developing ducklings. These results support the hypothesis that prey availability may influence harlequin reproductive effort (Bengtson and Ulfstrand 1971; Gardarsson and Einarsson 1994).

Initially we predicted that, following the flood in 1996, there would be reductions in both numbers of harlequins and prey abundance. Our hypothesis was supported by decreases in numbers of harlequin females, broods and *D. gilvipes* in 1996. There are many possible factors contributing to these declines including, unfavorable changes in stream habitat,

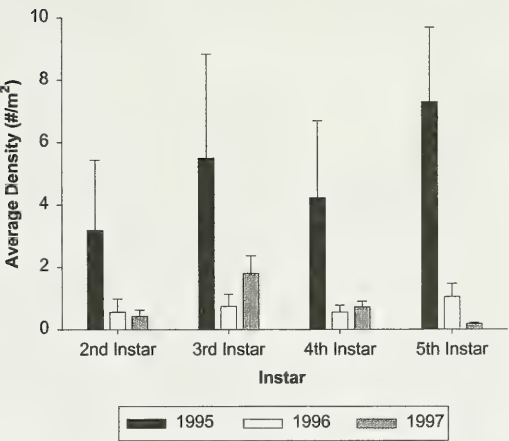


FIGURE 4. Average densities (#/m²) (with 1 SD) of the individual *Dicosmoecus gilvipes* life stages in 1995, 1996, and 1997 in Quartzville Creek, Oregon.

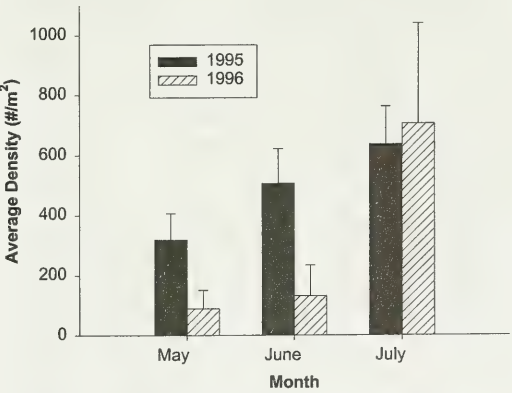


FIGURE 5. Average monthly densities (#/m²) (with 1 SD) of total benthic macroinvertebrates in 1995 and 1996 in Quartzville Creek, Oregon.

unsuitable nesting habitat, and impacts on the stream food web. Despite local changes in stream habitat, there were few changes in overall substrate composition following the 1996 flood (Wright 1997). Because harlequins have relatively high site fidelity (e.g., Bruner 1997), changes in riparian habitat may have affected nesting success. However, seven of nine previously used nest sites were intact following the flood (Bruner 1997), and we presume unsuitable nesting habitat was not a significant factor in reducing harlequin numbers in 1996. While many other possibilities exist, we suggest one plausible explanation for a decrease in Harlequin Ducks during the summer following the flood was the association between harlequins and their preferred prey *D. gilvipes*.

Abundance of macroinvertebrates in spring also may influence whether harlequins remain in the Quartzville Creek system to reproduce in a particular year. For example, most of the potential reproductive ducks observed in 1996 spring surveys left the Quartzville Creek system prior to incubation. This pattern corresponded with reduced caddisfly and benthic macroinvertebrate densities that spring. Similar examples of resource-tracking have been observed in other waterfowl species (Baldassarre and Bolen 1994; Krapu et al. 1983; Smith 1996*; Smith 1970; Swanson et al. 1974; Swanson and Meyer 1977), and we hypothesize that harlequin persistence and reproductive success in Quartzville Creek depends upon macroinvertebrate resource availability, particularly during breeding.

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Serum Profiles of American Elk, *Cervus elaphus*, at the Time of Handling for Three Capture Methods

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American Elk (*Cervus elaphus*) are captured using a variety of techniques and each may inflict various types of stress and/or injury that could affect animal well-being. We compared serum profiles of 25 free-ranging elk captured by helicopter net-gunning ($n = 7$), modified Clover traps ($n = 7$), and corraling ($n = 11$) in the Black Hills, South Dakota. Glucose, aspartate aminotransferase, and lactic dehydrogenase levels were higher in Clover-trapped elk than corralled or net-gunned elk. Potassium and creatinine kinase levels were higher in elk captured by corraling than elk captured by net-guns or Clover traps. Bilirubin was higher in Clover trapped and corralled elk compared to net-gunned elk. Our results suggest (1) techniques requiring less time from capture to release (i.e., net-gunning) significantly reduce tissue and muscle damage versus methods in which elk were confined for longer periods of time (i.e., Clover trapping and corraling), (2) limiting the time elk are restrained to < 24 hours in corrals may reduce muscle and tissue damage, (3) several serum parameters should be measured in order to obtain a complete description of elk response to capture and restraint.

Key Words: American Elk, *Cervus elaphus*, biochemical parameters, capture, Clover trap, corraling, net-gun capture, serum chemistry, serum profiles, South Dakota

Capture of wildlife is often necessary in research studies and management activities. Minimizing harmful physiological effects on animals due to capture and restraint should be a primary concern because complications such as capture myopathy may occur (Fowler 1978; Spraker 1982; Beringer et al. 1996). Therefore, selection of an appropriate capture technique requires knowledge of the effects of capture and restraint on physiological parameters. American Elk (*Cervus elaphus*) are commonly captured using corral traps (Varland et al. 1978*), a variety of helicopter assisted techniques (Barrett et al. 1982; McCorquodale et al. 1988), and modified Clover traps (Thompson et al. 1989; Millspaugh et al. 1994). However, we are not aware of a study that compared serum parameters of elk captured by these techniques to determine if they have detrimental effects on physiological parameters.

The physiological response of elk to capture may be directly related to the severity of pre-sampling and post-capture events. For instance, corraling elk in winter requires herding elk by helicopter to holding facilities (Lovaas 1973), a process which may take several hours. Once in corrals, elk may be held for a few days before release. In contrast, animals

caught in Clover traps probably do not undergo severe muscle exertion pre-capture, yet may be restrained in traps for 8–10 hours before processing. Helicopter net-gunning minimizes overall handling time in comparison to other capture techniques, but typically invokes great muscle exertion pre-capture.

Wildlife biologists typically consider blood parameters to be baseline values, regardless of the capture method used to obtain them. However, the variation between capture methods in time required to obtain blood samples (< 15 minutes net-gunning to > 24 hours corraling), and the related variation in the capture experiences of the animals, is known and predictable. Therefore, we predict that the effects of the capture technique should manifest in proportional effects on stress related biochemical parameters. Our objective was to determine the effects of Clover trapping, helicopter net-gunning, and corraling on the biochemical parameters of serum samples drawn at the typical post-capture times afforded by each capture technique. We therefore assume that our serum values reflect the biochemical effects of each capture method. Further, it should be noted that the variation in animal handling times and techniques in our study is not a confound. It is, instead, indicative

of the primary factor of interest in this experiment: the effect of these capture techniques on biochemical parameters at the time of human handling.

Methods and Results

Blood from elk in Custer State Park (43° 45'N, 103° 22'W), South Dakota, was collected as part of an on-going comprehensive study evaluating the behavioral and physiological effects of human disturbances on elk. From 1 July 1993 to 30 August 1993, we captured 11 adult elk (4 yearling bulls, 1 branch-antlered bull, and 6 cows) and from 14 June 1995 to 8 August 1995, we caught 13 adult elk (8 adult cows and 5 branch-antlered bulls) in Custer State Park using modified Clover traps (Thompson et al. 1989) baited with salt (Millspaugh et al. 1994). We set traps at approximately 1900–2100 hours and began checking traps at 0600 hours. Therefore, we were unable to document the length of time elk were confined in traps before handling.

We physically restrained elk from outside the trap (Millspaugh et al. 1994) and immobilized each animal with a combination of 500 mg Telazol® (Fort Dodge Laboratories, Inc., Fort Dodge, Iowa, USA) and 60 mg xylazine hydrochloride (Millspaugh et al. 1995). Mean induction time was 4.6 minutes (Millspaugh et al. 1995). We collected blood < 10 minutes post-induction (time when animal could be approached safely) using a 5 ml syringe and a 22-gauge, 2.54 cm needle by jugular venipuncture. We

transferred blood to glass vacuum sealed tubes without anticoagulant. Vials were centrifuged within 2 hours post-release, serum was separated, and stored at -20°C.

On 13 August 1993, we captured and radio-collared 13 individual adult elk (5 cows and 8 bulls) in Custer State Park with a net fired from a Bell Jet Ranger helicopter. After the initial decision to capture a specific animal, it was caught within 10 minutes. When the time of pursuit was greater than 10 minutes, we aborted chase and selected an undisturbed elk for capture. Upon successful capture, we untangled the net, physically restrained, and hobbled the animal. We collected blood < 10 minutes post-restraint by jugular venipuncture into 5 ml serum vials without anticoagulant. Vials were centrifuged within 3 hours, serum was separated, and stored at -20°C.

From 6–8 December 1994, as part of park management activities, > 200 elk were captured in adjoining Wind Cave National Park using a corraling technique (Lovaas 1973; Varland et al. 1978*). Corraling involved herding elk with two Bell Jet Ranger helicopters into a fenced enclosure for further processing. It took about 2 hours to drive animals into the corrals. Twenty elk (10 males and 10 females) were physically restrained in a "squeeze chute" and radio-collared. We collected a blood sample from each collared elk's jugular vein using 5 ml syringes and 22-gauge needles. Blood was col-

TABLE 1. Mean (SD) of serum parameters from elk captured using modified Clover traps ($n = 7$), helicopter net-gunning ($n = 7$) and corraling techniques ($n = 11$) in Custer State Park and Wind Cave National Park, South Dakota, 1993–1995.

Serum parameter	Capture method		
	Clover trapped elk Mean (SD)	Net-gunned elk Mean (SD)	Corralled elk Mean (SD)
Albumin (gm/dL)	3.7 (0.5)	3.2 (0.7)	3.9 (0.4)
Alk. Phosphate (mu/mL)	212.3 (89.8)	173.4 (51.9)	184 (132.5)
ALT(SGPT) (mu/mL)	35.8 (9.4)	41.3 (40)	22.6 (6.6)
AST (mu/mL)**	120 (41.6)	47.1 (30.3)	62.6 (14.7)
Bilirubin (mg/dL)**	0.7 (0.3)	0.2 (0.2)	0.7 (0.2)
BUN (mg/dL)	19.6 (3)	22 (4.9)	19.4 (3.4)
Calcium (mg/dL)	8.7 (1.3)	8.2 (1.5)	7.8 (2)
Chloride (mmol/L)	103 (14.3)	100.3 (14.5)	102.2 (4.7)
Cholesterol (mg/dL)	53.3 (9.1)	47.4 (10.4)	62.3 (7.5)
Cortisol (µg/dL)	4.6 (1.5)	4.5 (0.7)	3.8 (0.8)
CK (mg/dL)**	1.1 (0.2)	0.9 (0.2)	2.5 (0.2)
GGT (mu/mL)	27.6 (19.6)	28 (11.8)	40.5 (12.7)
Glucose (mg/dL)**	221.2 (28.4)	154.7 (32)	140.7 (39.3)
Iron (ug/dL)	192.9 (104.8)	150.9 (127.4)	140.2 (75)
LDH (mu/mL)**	1381.6 (224.3)	275.6 (90.7)	231.9 (32)
Phosphorous (mg/dL)	5.6 (1.5)	4.4 (1.9)	3.6 (1.1)
Potassium (mmol/L)**	4.8 (1.3)	4.4 (1.7)	13.3 (4.9)
Sodium (mmol/L)	139.3 (17.9)	136 (20.9)	125.7 (6.4)
Total Protein (gm/dL)	5.7 (0.9)	5.6 (1.1)	6.7 (0.8)
Triglyceride (mg/dL)	36.3 (15.8)	52.4 (51.4)	33.3 (12.1)
Uric Acid (mg/dL)	0.9 (0.6)	0.5 (0)	0.6 (0.2)

** indicates parameter differs among capture methods ($P < 0.05$).

lected within 5 minutes of restraint in the chute. We immediately transferred blood to glass vacuum tubes containing no anticoagulant and centrifuged each sample within 10 minutes of collection. Serum was removed and stored at -20°C . Due to a lengthy handling and sorting procedure, and disease testing, our samples were collected between 2 hours to 3 days post-capture. As a result, our data represent averages across animals over the three days of corral confinement.

We shipped 32 serum samples: $n = 10$ net-gun (5 bulls and 5 cows); $n = 10$ Clover trap (4 bulls, 6 cows); $n = 12$ corral (3 bulls and 9 cows) to the Wisconsin Regional Primate Research Center (WRPRC) at the University of Wisconsin-Madison, where samples were stored at -70°C until hormone and hematological assays were performed. We assayed several serum parameters including cortisol ($\mu\text{g/dL}$), glucose (mg/dL), blood urea nitrogen (BUN) (mg/dL), creatinine kinase (CK) (mg/dL), uric acid (mg/dL), cholesterol (mg/dL), triglycerides (mg/dL), aspartate aminotransferase (AST) (mu/mL), lactate dehydrogenase (LDH) (mu/mL), bilirubin (mg/dL), gamma-glutamyl transpeptidase (GGT) (mu/mL), serum glutamate pyruvate transaminase (SGPT) (mu/mL), total protein (gm/dL), albumin (gm/dL), alkaline phosphatase (mu/mL), calcium (mg/dL), phosphorus (mg/dL), iron (ug/dL), sodium (mmol/L), potassium (mmol/L), and chloride (mmol/L). These serum parameters are frequently used as indicators of physiological stress and condition (Spraker 1982; Jessup et al. 1982; Kock et al. 1987a,b; Delguidice et al. 1990; Morton et al. 1995).

An existing cortisol enzyme immunoassay at the assay labs of the WRPRC was validated for elk. A serial dilution of pooled elk serum demonstrated parallelism with the standard curve, and recoveries from spiked standards were near 100%, indicating a lack of serum interference with the assay. All serological parameters were measured at General Medical Laboratories, Madison, Wisconsin with a Synchron Clinical Systems CX7 Delta automated clinical chemistry analyzer (Beckman, Brea, California, USA). We compared mean serum parameters among capture groups (net-gun, Clover traps, corraling) using analysis of variance in GLIM (Aitkin et al. 1994) and Tukey's Least Significant Difference for posthoc multiple comparisons (Steele and Torrie 1980). Seven samples had hemolysis and were removed from the analysis. Therefore, analyses were conducted on 25 serum samples total (helicopter net-gunning $n = 7$, modified Clover traps ($n = 7$), and corraling ($n = 11$)).

Glucose, CK, AST, LDH, bilirubin, and potassium differed among capture groups (Table 1). Subsequent testing of group means indicated that glucose, AST, and LDH levels were higher ($P < 0.05$) in Clover trapped elk than elk captured by the

other two techniques. Potassium and CK were significantly higher ($P < 0.05$) in corralled elk compared to net-gunned or Clover trapped elk. Bilirubin was higher ($P < 0.05$) in Clover trapped and corralled elk compared to net-gunned elk. No mortality was observed in elk for which serum was analyzed.

Discussion

We attribute differences in serum parameters among capture groups to differences in the duration and intensity of physical activity during the capture process and subsequent period of confinement. Capture techniques requiring less time from capture to release (i.e., net-gunning) had less impact on serum parameters indicative of tissue and muscle damage than capture methods in which elk were confined for longer periods of time (i.e., Clover trapping and corraling). This finding is important because elevated levels of some serological parameters we observed may have compromised animal safety. For instance, potassium levels we recorded for corralled elk (13.3 mmol/L) (Table 1) are associated with muscle and tissue damage (McAllum 1985). Furthermore, increased potassium is a major component in the pathogenesis of capture myopathy (Kock et al. 1987a). McAllum (1985) reported that potassium levels of 28 mmol/l in the European Red Deer (*Cervus elaphus*) were considered four times higher than normal and contributed to sudden death in Red Deer. McAllum (1985) speculated that death in Red Deer resulted from cell swelling and degeneration owing to water passively entering the cells. The high potassium levels we observed among corralled elk could also be a result of injuries sustained from contact with each other in confined quarters, the fence, or during pursuit (Jago et al. 1997).

To avoid compromising animal safety, we recommend that the time of confinement in corrals be limited to < 24 hours. Further inspection of our data indicates that elk held in corrals < 24 hours ($n = 4$) exhibited mean potassium levels of 9.1 mmol/L , whereas elk held for > 24 hours ($n = 7$) displayed mean potassium levels of 15.7 mmol/L . Therefore, limiting the time elk are restrained in corrals to < 24 hours may decrease muscle and tissue damage, and reduce the possibility of capture myopathy. This could be accomplished by corraling only as many animals as can be processed in a day.

Elevated levels of other serum constituents also suggest a large degree of physical exertion and subsequent muscle damage in elk captured in corrals and by Clover traps. High levels of AST, CK, and LDH are used to index muscle damage (Rose et al. 1970; McAllum 1985; Kock et al. 1987a) and illustrate death of cellular material (Bubenik 1982). Elevated bilirubin in Clover trapped and corralled elk suggests hemolysis due to physical exertion (White et al. 1991). Heightened levels of LDH indi-

cates possible muscular degeneration, hemolysis, shock, and prolonged exercise (Moss et al. 1987; Noakes 1987) in Clover trapped animals. Last, elevated glucose levels in Clover trapped animals may be a result of excitability (Franzmann and LeResche 1978), muscle exertion, and resultant increase of adrenal catecholamines secretion (Kock et al. 1987a). However, immobilization by xylazine hydrochloride may also influence glucose levels (Seal et al. 1972).

Cortisol, a common measure of capture stress, did not differ among capture methods. This result suggests that glucocorticoids alone may not be a reliable indicator for comparing the physiological effects of capture on elk from samples collected at the time of animal handling for these techniques. Furthermore, glucocorticoids do not effectively document muscle and tissue damage as do other serum constituents. Hence, we recommend several serum parameters be measured and compared in order to obtain a more complete description of the physiological response to capture. This conclusion is further supported by recent findings in laboratory animals that different stressors evoke different characteristic profiles of hormonal and physiological responses (Kopin 1995).

Baseline serum parameters of all constituents were examined are not readily available for elk. However, Wolfe et al. (1982) and Pedersen and Pedersen (1975) suggest their elk blood data represent "normal" levels. Of the parameters reported in our study, Wolfe et al. (1982), and Pedersen and Pedersen (1975), the only one that appears markedly different is cholesterol. Elk in CSP and WICA appear to have lower cholesterol levels than those reported by Wolfe et al. (1982) or Pedersen and Pedersen (1975). Cholesterol is a good indicator of dietary condition in Moose, *Alces alces* (LeResche et al. 1974) and possibly in elk (Bubenik 1982), although detrimental levels of cholesterol in elk are unknown. Other researchers have reported biochemical profiles of elk serum (Herin 1968; Knight 1969; Vaughn et al. 1973; Weber and Bliss 1972), however, these data report only a small portion of the serum parameters we evaluated, are from different populations, and various seasons, and sexes, making direct comparisons with our data problematic. We recommend that researchers document baseline values for these serum constituents in elk. Furthermore, given the differences we observed in serum parameters among capture techniques, valid comparisons of animal condition from serum profiles can only be made when samples are collected from elk captured by the same technique. Other techniques, such as non-invasive measures of stress (Millspaugh 1999) should be explored further in studies of ungulate physiology.

Even greater standardization of blood sampling procedures and larger sample sizes may have yielded

more meaningful results during our study, but complete standardization of sampling procedures among these capture methods is not logistically feasible in many cases. For example, in field studies, it is not possible to continually monitor all Clover traps and process each animal immediately after capture. However, we were able to roughly standardize the time from human handling to sampling in our study.

In conclusion, our data suggest that corralling and Clover trapping elk elevates several biochemical parameters which are indicative of muscle and tissue damage. Sustained levels of these parameters may lead to, or be indicative of, complications such as capture myopathy. Hence, minimizing the time of holding may result in less disruption of physiological parameters. Therefore, we recommend that elk captured using corralling techniques be held for < 24 hours. Also, Clover traps should be monitored as frequently as possible, and captured elk should be processed as soon as possible. Because the effects of capture could manifest in both short and long-term serum parameters, we recommend several physiological variables be measured in order to obtain a more complete description of the stress response among various capture methods.

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Habitat Use, Movements, and Survival of American Black Duck, *Anas rubripes*, and Mallard, *A. platyrhynchos*, Broods in Agricultural Landscapes of Southern Québec

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American Black Duck and Mallard females were equipped with radiotransmitters in order to identify habitats used during brood-rearing, to quantify brood movements and to assess survival. The majority (96%) of the 134 brood sightings were made on waterways: 59% on streams, 19% in ditches, and 19% on mill ponds created on these streams. Mean proportions of sightings per brood were greater on streams (64%) and ditches (31%) for Black Ducks (64%), whereas for Mallards these were greater on streams (43%) and mill ponds (37%). Broods of both species made extensive movements, mainly along waterways. Overland movements and maximum distances from the nest were greater for Black Ducks than for Mallards. Daily survival rates (DSR) of broods of both species were similar. DSRs were lower for Class I broods (0.921) than for Class II broods (0.988). The probability of broods of both species surviving to 30 days was relatively similar (95% CI for Black Duck: 0.134–0.206, 95% CI for Mallard: 0.186–0.232). Results of this study indicate a lack of adequate brood-rearing marsh habitat in the agricultural landscapes of southern Québec where extensive drainage work has been carried out.

Key Words: American Black Duck, *Anas rubripes*, Mallard, *Anas platyrhynchos*, brood survival, habitat, Mallard, agricultural landscapes, movements, Québec.

In eastern North America, the American Black Duck (*Anas rubripes*) population has declined during the last 30–40 years (Rogers and Patterson 1984; Rusch et al. 1989), whereas an increase has been noticed in the closely related Mallard (*Anas platyrhynchos*) (Johnsgard and DiSilvestro 1976; Heusmann 1991). Many potential causes have been considered to explain the Black Duck decrease, including habitat degradation or loss (Dennis et al. 1985; Diefenbach and Owen 1989), overharvest (Grandy 1983), pollution (Longcore and Stendell 1982; Haramis and Chu 1987), changes in Black Duck productivity (Krementz et al. 1992; Bélanger et al. 1998), and competition/hybridization with the Mallard (Brodsky and Weatherhead 1984; Ankney et al. 1987; Merendino and Ankney 1994). Annual survival rates of sympatric populations of Mallards and Black Ducks are not different, suggesting that differences in trends could be attributed to differential immigration or natality (Nichols et al. 1987). Mallards might have a higher reproductive rate through larger clutch sizes and more persistence in reneesting (Ankney et al. 1987). Large-scale habitat modifications brought about by land-clearing for agriculture may have benefited the Mallard to the detriment of Black Ducks, although evidence for such an hypothesis is weak (Nudds et al. 1996). It is argued that Mallards exclude Black Ducks from productive wetlands (Merendino et al. 1993; Merendino

and Ankney 1994). Competition between the two species could lead broods to make more and longer movements in search of adequate habitats and, as many authors consider that brood survival is negatively related to distance of movements (Ball et al. 1975; Rotella and Ratti 1992a; Seymour and Jackson 1996), Black Duck brood survival could be negatively affected. The objectives of our study were to verify if differential movement patterns and survival rates of Black Duck and Mallard broods in agricultural landscapes could be contributing to the differing population trends of the two species.

Study Area

Our study areas consisted of two neighbouring watersheds, those of the Boyer (217 km²; 46° 46' N, 70° 57' W) and Le Bras (220 km²; 46° 35' N, 71° 06' W) rivers located on the south shore of the St. Lawrence River, near Québec City. Landscapes of both watersheds are dominated by agriculture, which covers around 65% of the area. Woodlots (28–29%), peatland (2–4%) and marginal habitat (2–3%: abandoned farmland, riparian strips and hedgerows) are the other types of upland habitats.

Permanent streams are the main type of wetland in both watersheds, totaling 298 km and 304 km for the Boyer and Le Bras watersheds respectively. Most of these streams circulate in agricultural lands; only 8.5% of the streams in the Boyer watershed have

their banks forested on both sides, this proportion being of 3.5% in the Le Bras watershed. Subsurface irrigation drainage has been installed in most farmland, and to facilitate evacuation of water coming from this drainage system, nearly 70% of these streams have been straightened and deepened. This eliminated most marshes within these watersheds, with the exception of a few oxbow lakes, mill ponds and gravel pit marshes. Numerous farm ponds (179 in the Boyer watershed and 94 in the Le Bras watershed) and peatland pools are the only other wetlands available.

Aerial surveys done in these watersheds indicated that Black Ducks and Mallards were the most abundant breeding duck species, comprising nearly 90% of total indicated breeding pairs, with a Black Duck to Mallard ratio of 3:1 (C. Maisonneuve, R. McNicoll, and A. Desrosiers, unpublished report).

Methods

Field methods

Between 18 April and 6 May 1994-1996, we used modified decoy traps (Sharp and Lokemoen 1987) to capture female Black Ducks and Mallards from streams and ponds. Females of both species were used as decoys. We processed and released all birds upon capture, and we released male and female birds together that were captured simultaneously. We banded all birds with standard U.S. Fish and Wildlife Service leg bands, and radiomarked females with transmitters (models 7pn and TSA2000, ATS Inc., Isanti, Minnesota, USA) attached with backpack harnesses (Dwyer 1972). We captured and radiomarked 62 female birds. Even with a Black Duck to Mallard ratio of 3:1, more Mallards ($n = 33$) were caught than Black Ducks ($n = 29$), possibly due to a greater wariness of this species. Of these females, 53 were defined as breeding residents (C. Maisonneuve, R. McNicoll, and A. Desrosiers, unpublished report). Nesting was initiated by 45 of these, and 9 renested after loss of their initial nests to predators. Low nesting success, mainly due to high predation rates, led to the hatching of only 16 broods (8 Mallards and 8 Black Ducks).

Radio-tracking of broods was carried out on foot by homing with a 2-element H antenna and a scan-

ning receiver. Because of high predation rates, only 16 nests produced broods. Tracking effort was thus reduced accordingly and the mean time span between two successive locations of one brood was 2.8 days. Occasional flights were made to relocate females for which signal was lost on the ground. At each brood location we recorded brood size, habitat type, and the following habitat variables: stream or pond width, shore slope and height, riparian strip width, and percent cover of open water, emergent and submerged vegetation. Water depth, not considered a reliable variable because of fast and considerable water level fluctuations related to the extent of agricultural drainage, was not measured. Habitat types were categorized as follows: stream, ditch (man-modified stream), natural lake, mill pond, farm pond, oxbow lake, sand or gravel pit pond, wet depression in field, and peatland pool. For convenience in some analyses and discussion, streams and ditches are often grouped together as waterways.

Statistical analysis

Because so few broods could be tracked, data from all three years were pooled for analysis. Brood daily survival rates (DSRs) were determined with the Mayfield (1961, 1975) method, as adapted by Ringelman and Longcore (1982a). Absence of independence in the survival of ducklings from the same brood does not bias DSR estimates, but underestimates the variance (Ringelman and Longcore 1982a; Pollock et al. 1989; Mauser et al. 1994; Flint et al. 1995). Thus, the method proposed by Flint et al. (1995) was used to estimate standard errors for brood DSRs. As survival may vary with brood age, with most mortality occurring in the first few days after hatching (Dzubín and Gollop 1972; Ball et al. 1975; Ringelman and Longcore 1982a; Talent et al. 1983), it is recommended to divide brood-rearing into periods of reasonably stable survival rates (Johnson 1979; Bart and Robson 1982; Heisey and Fuller 1985). Considering that few broods could be tracked after the age of 30 days, brood-rearing was divided in two periods (0-18 days and 19-30 days) according to the duckling age classification of Gollop and Marshall (1954), and DSRs were determined for these separate periods. DSR for the entire

TABLE 1: Distribution of brood sightings and mean proportion of sightings per brood among habitat types.

	Black Duck			Mallard		
	<i>n</i>	%	Mean proportion of sightings/brood (%)	<i>n</i>	%	Mean proportion of sightings/brood (%)
River	46	80.7	63.8	33	46.4	42.6
Mill pond	2	3.5	2.5	23	29.9	37.3
Ditch	7	12.3	31.3	18	23.4	11.0
Farm pond	0	0.0	0.0	2	2.6	3.9
Wet depression	2	3.5	2.3	1	1.3	1.9
Total	57			77		

TABLE 2. Comparison (median test) of variables of movements made by American Black Ducks and Mallards in agricultural landscapes of southern Québec, 1994-1996.

Variable	Black Duck			Mallard			χ^2	P
	Median	Mean	Range	Median	Mean	Range		
Number of locations	14.0	11.8	6 - 15	12.5	10.9	1 - 21	0.11	0.735
Length of location period	34	31.8	14 - 50	35	31.5	1 - 59	0.11	0.735
Total number of movements	11.0	10.4	8 - 14	5.5	6.9	1 - 18	1.47	0.225
Number of downstream movements	5.0	4.4	2 - 6	1.0	3.0	0 - 9	0.58	0.447
Distance of downstream movements (m)	3900	3264	1300 - 4160	420	2169	0 - 6330	0.58	0.447
Number of upstream movements	4.0	3.8	2 - 6	0.5	2.1	0 - 7	1.47	0.225
Distance of upstream movements (m)	3300	3124	1580 - 5340	1210	1335	0 - 4640	0.58	0.447
Number of overland movements	2.0	2.2	1 - 4	1.0	1.8	1 - 5	0.58	0.447
Distance of overland movements (m)	1800	2020	260 - 3800	690	975	200 - 2900	3.46	0.063
Maximum distance from nest (m)	3250	3470	2200 - 4800	1750	1918	800 - 3800	3.46	0.063
Total distance traveled (m)	8126	8414	6160 - 13 040	3185	4482	920 - 10320	0.58	0.447
Number of movements made during the first 10 days	5	4.2	2 - 5	3	3.4	1 - 8	1.47	0.225
Distance traveled during the first 10 days (m)	5970	4906	2570 - 9960	2043	2797	200 - 6040	0.58	0.447

brood-rearing period (30 days) was obtained by multiplying DSR estimates of both periods elevated to the length of respective periods (Johnson 1979; Ringelman and Longcore 1982a):

$$S = (DSR_I^{18}) \times (DSR_{II}^{12}).$$

Variance of the survival probability estimate for the entire brood-rearing season (30 days in this case) was obtained after Goodman (1960):

$$\begin{aligned} \text{Var}(S) = & \{(DSR_I^{18})^2 \times \text{var}(DSR_{II}^{12})\} \\ & + \{(DSR_{II}^{12})^2 \times \text{var}(DSR_I^{18})\} \\ & + \{\text{var}(DSR_I^{18}) \times \text{var}(DSR_{II}^{12})\} \end{aligned}$$

We used program CONTRAST (Hines and Sauer 1989; Sauer and Williams 1989) to test for differences in DSRs of broods among years and habitats, and between species.

Each brood location was mapped at a 1:20 000 scale, and the following distances were measured directly on the maps: (1) distance between nest and first brood-rearing site used for more than one day, (2) distance between each successive location, (3) total distance of downstream, upstream and overland movements, (4) total distance traveled, and (5) maximum distance from the nest (straight-line distance between nest and farthest brood location). Overland movements were measured as straight lines between two locations, and total stream length was measured between successive locations made on the same stream. Numbers of movements and distances traveled by both species were compared with median tests.

Results

Habitat selection

Of the 16 broods produced, two Black Duck broods disappeared immediately after hatching, before any sighting could be made. Most of the 134 sightings of the other 14 broods (8 Mallards and 6 Black Ducks) were on rivers (59.3%), followed by ditches (19.3%) and mill ponds (17.9%) (Table 1). Only three sightings of three different broods were made in temporary wet depressions in fields, and two others were made on farm ponds. For both species, mean proportion of sightings per brood was also higher on streams (Table 1). For Black Duck broods, mean proportion of sightings in streams and ditches totaled 95%. For Mallards, this proportion of sightings made in waterways was much lower (53.6%) because of a greater mean use of mill ponds (37.3%). Only 13 of the brood sightings were made on stream sections where both banks were forested.

Brood movement and survival

Mean distance traveled by females and their broods between nesting sites and first brood-rearing sites was 2.7 km. Distances of up to 7 km were even traveled by broods produced from peatland nests.

TABLE 3. Comparison of daily survival rates (DSR) between age classes and species of American Black Duck and Mallard broods in agricultural landscapes of southern Québec, 1994-1996.

Groups compared	DSR	SE	χ^2	<i>P</i>
Black Duck, class I	0.9245	0.0130	29.14	< 0.0001
Black Duck, class II	0.9704	0.0146		
Mallard, class I	0.9190	0.0112		
Mallard, class II	0.9963	0.0037		
Black Duck, class I	0.9245	0.0130	0.10	0.749
Mallard, class I	0.9190	0.0112		
Black Duck, class II	0.9704	0.0146	2.97	0.085
Mallard, class II	0.9963	0.0037		
Black Duck, class I	0.9245	0.0130	5.51	0.019
Black Duck, class II	0.9704	0.0146		
Mallard, class I	0.9190	0.0112	43.00	< 0.0001
Mallard, class II	0.9963	0.0037		
Class I	0.9212	0.0085	46.62	< 0.0001
Class II	0.9875	0.0054		

These were all Black Duck broods, explaining why first distances traveled by broods of this species ($3.5 \text{ km} \pm 0.9$) were longer than those traveled by Mallard broods ($2.0 \text{ km} \pm 0.5$). This difference, however, was not significant (median test: $\chi^2 = 1.6$, $df = 1$, $P = 0.20$).

Tracked broods made 1-18 movements, covering a total of 920-13 040 m (Table 2). All broods made at least one overland movement, the maximum being five. Total distance traveled overland varied from 200 to 3800 m. Up to nine downstream movements were made by a single brood, the maximum number of upstream movements was seven. Total distance traveled downstream varied from 0 to 6330 m, whereas upstream movements totaled distances of 0 to 5340 m. Of the 82 movements noted along streams (rivers and ditches), 36 (44%) were downstream and 46 (56%) were upstream. Mean daily distance traveled was 190 m, varying from 30 to 1500 m. Maximum distance from nest was 2500 m. The brood which stayed the closest to the nest strayed only 800 m from it, and the brood which strayed the most was found 4800 m from the nest. Among all the comparisons which could be made between Black Duck and Mallard brood movements, only total distances traveled overland and maximum distances from nests indicated significant differences (Table 2), movements made by Black Ducks being greater than those of Mallards.

For Black Ducks ($n = 6$) as well as Mallards ($n = 8$), only 50% of broods had at least one of their ducklings survive to the age of 30 days. Among Black Duck ducklings, 30.6% ($n = 36$) survived to that age, whereas this proportion was of 32.9% ($n = 73$) for Mallard ducklings. This slight difference was not significant ($\chi^2 = 0.03$, $df = 1$, $P = 0.861$). Total brood loss cases were mostly concentrated at the beginning of the brood-rearing period: five

occurred within 18 days from hatching (class I broods), and the other two cases occurred less than 30 days after hatching.

DSRs of Black Duck and Mallard broods differed significantly between age classes (Table 3). For both species, DSR was significantly less for class I broods than for class II broods. Class I brood and Class II brood DSRs were similar for both species. As DSRs were not the same for the two brood-rearing periods considered, in order to obtain a brood survival probability for the entire 30-day period, estimates obtained separately for both periods were multiplied. A brood-survival probability of 0.170 was obtained for Black Duck broods, the value obtained for Mallards being 0.209. Considerable overlap was obtained between the CIs of the two species (95% CI for Black Duck: 0.134-0.206, 95% CI for Mallard: 0.186-0.232).

No significant correlation was obtained between brood-survival rate probabilities and the distance traveled by these broods (Table 4). Survival probability to the age of 10 days for broods which traveled distances totaling at least 3150 m (mean distance traveled in the first 10 days after hatching) did not differ from that of broods which traveled less (median test: $\chi^2 = 1.74$, $df = 1$, $P = 0.187$).

TABLE 4. Spearman rank correlation between survival probability rates and distance traveled by American Black Duck and Mallard broods in agricultural landscapes of southern Québec, 1994-1996.

Period	Distance	<i>r</i>	<i>P</i>
10 first days	total	0.31	0.312
30 days	total	-0.21	0.495
30 days	overland	0.03	0.931
30 days	maximum from nest	-0.20	0.504

TABLE 5. Numbers and distances of movements of American Black Duck and Mallard broods from different studies.

Species	Sighting frequency	Number of movements	Total distances traveled	Distances traveled overland	Distances between nest and first rearing site	Study
Black Duck	Mean 1 / 2.8 days	8 - 14	6 - 13 km	0.3 - 3.8 km	Mean of 3.5 km	Our study
	1 - 2 / day	Mean of 2	Mean of 8.4 km	Mean of 2.0 km	0.1 - 7.4 km	Krementz and Pendleton 1991
	2 - 3 / day	Maximum of 10	Mean of 3.7 km		Mean of 2.3 km	Ringelman and Longcore 1982b
			Maximum of 6.5 km		Maximum of 6 km	Seymour and Jackson 1996
Mallard			6 - 21 km	1.8 - 3.3 km	Mean of 1.2 km	
			(downstream movement of 13 broods)			
	Mean 1 / 2.8 days	1 - 18	1 - 10 km	0.2 - 2.9 km	Mean of 2.0 km	Our study
			Mean of 4.5 km	Mean of 1.0 km	0-3 - 4.2 km	
				0.9 - 2.4 km		
				Mean of 1.6 km	0.6 - 3.8 km	Berg 1956
					Median of 0.9 km	Cowardin et al. 1985
	1 - 4 / day	week 1: most broods: 2 - 3 week 2: 1 - 5, mean of 1.2 after: 0 - 12		Median of 0.9 km	Mean of 0.2 km for broods surviving up to 14 days	Dzus and Clark 1997
					Mean of 0.3 km for broods not surviving	
	1 - 2 / day	Mean of 2	Mean of 3.3 km		Mean of 2.4 km	Krementz and Pendleton 1991
		Maximum of 23	Maximum of 6.6 km		Maximum of 5.2 km	
	1 - 8 / day	1 - 12	0.1 - 7.0 km		0.1 - 3.1 km	Rotella and Rati 1992b
	1 - 8 / day	11 broods stable on a pond 14 mobile broods (2 - 10 ponds)		Maximum of 2.4 km straight line Cumulative maximum of 5.6 km		Talent et al. 1982, 1983

TABLE 6. Survival probability estimates for American Black Duck and Mallard broods from different studies.

Black Duck	Mallard	Study ^a
0.17 (30 days) ^b	0.21 (30 days)	Our study
	0.44 (60 days)	Ball et al. 1975
	0.39 (30 days)	Chouinard and Arnold 1997
	0.28 - 0.36 (30 days)	Dzus and Clark 1996
	0.32 - 0.62 (30 days)	Howerter et al. 1997
0.16 - 0.58 (24 days)	?	Krementz and Pendleton 1991
	0.40 (60 days)	Orthmeyer and Ball 1990
0.34 (60 days)		Reed 1975
0.42 (60 days)		Ringelman and Longcore (1982a)
	0.35 (60 days)	Talent et al. 1983
	0.35 - 0.38 (30 days)	Yarris et al. 1997

^aStudies considering cases of total brood loss^bLength of brood-rearing period considered

Discussion

The majority (78%) of brood sightings were made on streams and ditches. The proportion of brood sightings made on waterways was even greater (96%) when mill ponds were included, these ponds being enlargements of existing streams created by old dams. Mean proportions of sightings per brood were highest in streams for both species, but second most used habitats were ditches for Black Ducks and mill ponds for Mallards. Farm ponds and wet depressions in agricultural fields seemed to be used only occasionally and temporarily. Farm ponds in the study area, although relatively numerous, covered an average of 0.17 ha, well under the lower limit of 0.5 ha usually considered adequate for providing waterfowl brood-rearing habitat (Lokemoen 1973; Hudson 1983; Rumble and Flake 1983; Svingen 1991). Apparently, the lack of marsh-type wetlands in these extensively drained landscapes forced broods to use the only habitats where there is a minimum area of permanent water available. Less than 10% of brood sightings were made on stream sections passing through woodlots. This could be due to the low availability of streams with forested banks, but observations indicate that broods which have access to such habitats do not readily use them and, when they do penetrate such habitats, it is usually to move to the other side of the forested area.

For Black Ducks, whether in island-nesting populations raising their broods in coastal salt marshes (Reed 1975) or in inland forest-nesting populations (Ringelman and Longcore 1982b), broods usually leave the nest within 24-72 hours of hatching, make one major move to a rearing site within the first week after leaving the nest, and make few subsequent movements. However, this pattern may be modified in landscapes where brood-rearing habitat has been fragmented, forcing broods to move further between feeding sites (Krementz and Pendleton 1991). Landscapes in our study areas have been extensively modified by agriculture, leading to a high level of

habitat fragmentation, and drainage of agricultural lands has affected availability of adequate wetlands. The broods we tracked in those landscapes moved almost constantly. Moreover, due to low numbers of broods which could be tracked, tracking effort was reduced to a few days per week. A mean interval of 2.8 days obtained between successive observations of a brood, making it likely that additional movements were made during that time without being noticed. The numbers and distances of movements reported should thus be considered as minimums.

Nonetheless, compared to results obtained in other studies, our values are among the highest for Black Ducks and Mallards (Table 5). Only Krementz and Pendleton (1991) report greater values for total number of movements. Ducks tracked in their study nested on coastal islands where brood-rearing habitat, essentially salt marshes, was greatly fragmented due to human encroachment, forcing broods to move from one habitat fragment to another. As for total distances traveled, only Seymour and Jackson (1996) reported greater values than obtained in our study (Table 5). But the greatest distances they reported were traveled by a small number (13) of females which seemed to represent extreme cases. The females involved nested at distances of 6-21 km from a salt marsh where they led their broods by traveling along streams. The same authors indicated that only 58.5% of 610 broods produced inland made movements to change habitat and that the probability of moving was related to the distance between the brood-rearing site and the salt marsh. It is not excluded that broods in the Boyer River watershed could make downstream movements to a salt marsh located at the mouth of the river and spend part of the brood-rearing period in that marsh. But distances are much too great, and obstacles (rapids) too numerous for broods produced upstream, like the ones we tracked, to make such movements.

Some studies indicate that the number of movements and distances traveled by broods are related to

density of wetlands, and thus to the availability of adequate brood-rearing habitats (Talent et al. 1982; Rotella et Ratti 1992b). The results of Dzus and Clark (1997) were not in agreement with this, but those authors attributed this to the fact that their study area was characterized by a wetland density much greater than those of previous studies. In low wetland-density conditions, broods have to make more movements in order to find adequate brood-rearing sites, and distances traveled are greater. Extreme values obtained in our study areas could thus be related to low wetland densities and to low quality of available habitats along streams.

Invertebrate availability is reported as one of the main factors in habitat selection by dabbling ducks (Murkin and Kadlec 1986). In the first few days after hatching, ducklings feed essentially from emerging adult insects captured at or near the water surface (Sugden 1973; Reinecke 1979). Around the age of 10-12 days, duckling behavior is modified and they begin eating invertebrates under water in deeper water. Observations we made indicate that broods using stream habitats seemed to feed at the surface and gleaned adjacent riparian vegetation. Observations made by Seymour (1984) confirmed this behavior for Black Duck broods in stream habitats, the author underlining that broods never moved to the riparian zone to feed. Channellization works in agricultural areas generally cause considerable modifications in benthic invertebrate populations (Lenat 1984; Barton 1996), possibly influencing availability of food for broods reared in this type of habitat. Hunter et al. (1984) showed that, when invertebrate abundance and biomass are reduced, movements made by ducklings are greater. Frequent and sudden water-level rises and associated streamflows caused by excessive drainage works may temporarily reduce invertebrate populations in affected streams and in adjacent riparian strips. These streams present unstable conditions, often characterized by important sedimentation during dry periods, and leaching of the substrate during floods. This instability could be one of the major causes of the extensive movements made by broods in our study areas.

In Chesapeake Bay, Black Duck and Mallard broods had similar movement patterns (distances between nest and first rearing site, distances traveled during secondary movements, and total distances traveled (Krementz and Pendleton 1991). All broods tracked by these authors originated from island nests and used the same type of rearing habitat after hatching. In our study, total distances traveled and maximum distance from nest were twice as great for Black Duck broods as for Mallard broods. This may be due to the fact that many of our Black Duck broods originated from nests in peatlands, habitats which were not used as much by Mallards (C. Maisonneuve, R. McNicoll and A. Desrosiers,

unpublished report) and which were often located far from the streams frequented during brood-rearing. Numerous pools are present in some of these peatlands. Water in these pools is very acidic (Glooschenko and Grondin 1988) and Black Ducks are reputed to avoid the most acidic situations (DesGranges and Darveau 1985; DesGranges and Houde 1989). Thus, all of the broods produced in this type of habitat made extensive movements out of the peatlands and into the adjacent agricultural landscape where they were found in stream habitats soon after hatching. Similar behavior of peatland nesting Black Ducks has been reported in forested areas of the Maritimes (Erskine 1987).

Survival of broods is often said to be inversely related to distances traveled (Ball et al. 1975; Rotella and Ratti 1992b; Seymour and Jackson 1996). Even though our results failed to corroborate this, it remains possible that the observed extensive movements could influence survival. As emphasized previously, distances reported are minimums. More frequent sightings might have permitted us to obtain more precise values, and probably of greater importance than those indicated, which already are among the greatest reported.

It is generally recognized that most cases of brood mortality occur before the age of 18 days and that most ducklings surviving to that age normally survive to fledging (Ball et al. 1975; Talent et al. 1983; Lokemoen et al. 1990; Orthmeyer and Ball 1990; Rotella and Ratti 1992a). Variations in survival rates obtained after 30 days are thus very low, and the rates obtained may be compared without much problem with survival rates obtained for the 60-day period preceding fledging (Rotella and Ratti 1992a). When calculating brood-survival rates, overestimation of recruitment may be caused by omitting cases of total brood loss (Ball et al. 1975; Reed 1975; Ringelman and Longcore 1982a; Talent et al. 1983). Radio-tracking of marked females enables identification of such total brood loss cases and eliminates this bias in evaluation of survival rates. Thus, comparisons of survival rates obtained in our study can only be made with those obtained in other studies that considered total brood loss. Survival rates obtained for Black Duck and Mallard broods raised in the Boyer and Le Bras River watersheds were lower than all those obtained in this way (Table 6). Only Krementz and Pendleton (1991) indicated values as low (16%) for Black Duck broods in one of two years of their study. These results, combined with the fact that movements made by broods were generally more extensive than those reported elsewhere, led us to believe that there is a lack of adequate brood-rearing habitat in the studied watersheds. Krementz and Pendleton (1991) used the same arguments to explain the low survival rates they obtained in Chesapeake Bay, where habitat fragmentation is

considerable, and where broods must make extensive movements. Food abundance does not seem to be a major limiting factor in non-modified habitats such as the forests of Maine (Reinecke 1977) or *Spartina* salt marshes of the St. Lawrence Estuary (Reed 1968, 1970). But our results, like those of Kremetz and Pendleton (1991), indicated that food abundance may act as a limiting factor in habitats perturbed by agriculture or human development.

The probability of a Black Duck brood surviving to 30 days was slightly less (17%) than that obtained for Mallard broods (21%). However, considerable overlap was obtained in the 95% CIs of the two species, indicating similar DSRs. These results agree with those obtained in other studies comparing brood survival rates for these two species. In Chesapeake Bay, survival of Black Duck broods was greater than that of Mallard broods during one of two years, no difference being noted during the other year (Kremetz and Pendleton 1991). No difference in brood survival was noted between Black Ducks and Mallards in another study carried out in New Brunswick (Petrie and Drobney 1997). Finally, comparison of brood sizes in Maine failed to detect any difference between Class IIc-III broods (37-55 days old) of each species (Longcore et al. 1998), which is another indication of lack of differential survival between Black Duck and Mallard broods. The same comparisons were made with data from aerial surveys carried out in 1992, 1993 and 1995 in the two watersheds we studied, and there were no differences between the two species in any of the survey years (C. Maisonneuve, R. McNicoll, and A. Desrosiers, unpublished report).

Our results, and those of Kremetz and Pendleton (1991) indicated that the survival probability is relatively low for Black Duck and Mallard broods raised in perturbed landscapes where they have to make extensive movements to find adequate feeding sites. Creation of quality brood-rearing habitats should thus be considered among the main actions in management strategies which aim to increase duck productivity in agricultural landscapes. Construction of series of weirs along small headstreams would help create a network of small wetlands which could easily be encountered by broods during their movements and be used as feeding sites, and would contribute to the reduction of streamflow and bank-erosion problems often encountered in agricultural landscapes modified by extensive drainage works.

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Threespine, *Gasterosteus aculeatus*, and Fourspine, *Apeltes quadracus*, Sticklebacks in the Lake Superior Basin

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The Threespine (*Gasterosteus aculeatus*) and Fourspine (*Apeltes quadracus*) sticklebacks are unintentionally introduced species to Lake Superior with initial populations established near Thunder Bay, Ontario. An examination of annual seining and trawling records show that native sticklebacks have declined in abundance in their native habitats as a result of these introductions. Assuming a single colonization event for Lake Superior, the distribution of *Gasterosteus* has been extended to the Black River, Ontario, in the east as well as both the Minnesota and Michigan coasts of Lake Superior. *Apeltes quadracus* is not known from Great Lakes populations outside of Lake Superior. However, specimens have been collected in Lake Superior waters distant from Thunder Bay. *Gasterosteus* has spread rapidly while *Apeltes* has not spread as quickly. *Apeltes*, due to its preference for nearshore areas, has the greatest potential to affect the native fish community negatively. This may occur through competition for habitat and food resources which can ultimately change the food web structure.

Key Words: *Apeltes*, *Culaea*, *Gasterosteus*, *Pungitius*, introduced species, Lake Superior.

The Fourspine (*Apeltes quadracus*) and Threespine (*Gasterosteus aculeatus*) sticklebacks, unintentionally introduced species, are now well established in the Thunder Bay area (48°24'N, 89°19'W) of Lake Superior, Ontario. *Apeltes* is normally restricted to eastern North America and is infrequently found in freshwater (Scott and Crossman 1973; Campbell 1992). In contrast, *Gasterosteus* has a nearly circum-polar distribution and frequents freshwater (Scott and Crossman 1973; Wootton 1976).

Apeltes, first captured at the mouth of the Neebing-McIntyre rivers (48°24'N, 89°13'W) at Thunder Bay in the summer of 1986 (Holm and Hamilton 1988), is absent from all Great Lakes except Lake Superior. Entry into Lake Superior thus suggests a marine or St. Lawrence River origin, presumably through ballast water transport (Holm and Hamilton 1988).

In addition to marine and freshwater populations on the east and west coasts of Canada, *Gasterosteus* is known from freshwater areas of the Hudson Bay Lowlands and the St. Lawrence and Ottawa rivers (Scott and Crossman 1973). Prior to 1980, *Gasterosteus* was present in the Great Lakes solely in Lake Ontario (Fleischer and Brazo 1985). By 1980 *Gasterosteus* had reached Lake Huron (Gibson 1982). *Gasterosteus* was collected in Lake Michigan in 1982 (Stedman and Bowen 1985). In 1987, *Gasterosteus* was collected in the southern portions of Neebing Marsh (48°23'N, 89°13'W), Lake Superior, at Thunder Bay (Hartviksen and Momot 1989). In 1988, *Gasterosteus* was recorded from

Lake Erie (ROM 44004). Hence, *Gasterosteus* is now present in all the Great Lakes.

Except for Lake Ontario, *Gasterosteus* seemingly has a limited distribution in most Great Lakes. Either low numbers have been collected or the species is not collected on a consistent basis in some repeatedly sampled areas (Stedman and Bowen 1985). Due to its earlier arrival to most of the lower Great Lakes, *Gasterosteus* may have entered Lake Superior from one of those areas. Transport within the bilges of oceangoing or interlake vessels was the probable method of introduction of this species to the Thunder Bay area.

Far less attention has been focused on the possible effects of *Apeltes* and *Gasterosteus* on native fish communities than on other recently introduced fish species such as: Ruffe (*Gymnocephalus cernuus*); Rudd (*Scardinius erythrophthalmus*); or the Round (*Neogobius melanostomus*) and Tubenose (*Proterorhinus marmoratus*) gobies (e.g., Crossman 1991; Jude et al. 1992). Reasons for this may include: (1) failure to consider them as a potential nuisance or threat to established fish communities, (2) initial low abundance in most areas, or, (3) in some cases, their co-existence within established fish communities (e.g., *Gasterosteus* in Lake Ontario) prior to their introduction into new areas. Historically, however, most non-intentional fish introductions have been detrimental to native fauna (Hartman 1988).

The objectives of the research reported here were to document the spread and increase in abundance of these two species within Lake Superior and to deter-

mine how these introductions might have, or will affect, the distribution and abundance of the native sticklebacks, the Brook Stickleback (*Culaea inconstans*) and the Ninespine Stickleback (*Pungitius pungitius*), in the Thunder Bay area.

Methods

Seining records (1984–1988, 1990–1992, 1995 and 1997–1998) from the ichthyology class of the Department of Biology, Lakehead University, made at Mission Marsh (48°20'N, 89°13'W), Lake Superior, as well as trawling records from the Ontario Ministry of Natural Resources (OMNR) Lake Superior Management Unit (LSMU), made in Thunder Bay Harbour (1991–1997) were enlisted to document changes in stickleback abundance and frequency of occurrence (percent of times each species was caught out of all trawl hauls made).

Seining typically took place over a two-hour period during a single day in mid-September to early-October. The sampled area extended 0.4 km upstream from the mouth of the Kaministiquia River. Two bag seines (2.0 m × 12.4 m × 6.3 mm) were used to sample representative habitat types including barren sand, cobble rock and sparsely and heavily vegetated areas. Sampling times were approximately equal in each habitat type. All fish were identified to species level and, except for large collections of very common species or large specimens, most were preserved.

The LSMU trawling program employed a 5.2 m bottom trawl (2.5 cm mesh body and a 64.0 mm mesh cod end). Towing runs lasted from 3–8 minutes (\bar{x} = 5 minutes). Trawling depth varied from 1.0–14.0 m, with the greatest depths restricted to river channels and some boat slips. Trawling initially (1991–1994) occurred within three distinct time periods; recent sampling (1995–1997) was directed toward autumn (late-September to late-October). Because the primary

purpose of the LSMU program was to detect the presence of ruffe, sticklebacks were not identified to species level in 1991–1992. All stickleback species were identified in the lab in 1993–1996 while identifications were made on board the trawling vessel in 1997. Frequency of occurrence was calculated for each stickleback species from 1993–1997.

Trawl and seine captured *Apeltes* and *Gasterosteus* were examined for their associations with other fish species. Recent personal collection records, collections made by biological consultants and identified by us, available published records and contact with personnel in museums and natural resource agencies were utilized to plot the current distribution of both species in Lake Superior.

To determine whether changes in the percent composition of stickleback species captured by fall trawling (1993–1997) and seining (1987–1998) were significant across years, we used analysis of variance ($\log_e + 1$ transformed) on the stickleback data and then the Newman-Keuls multiple comparison test to determine which pairs of means significantly differed. Correlation coefficients were calculated using the frequency of occurrence of fall trawl captured and percent composition of seine captured sticklebacks and then Bonferroni probabilities were used to identify relations between trends.

Results

Trawling records show that sticklebacks comprise a major proportion of the fish community inhabiting the Thunder Bay harbour and the lower portions of inflowing rivers (Table 1). Despite variation in annual effort and sampling periods, sticklebacks consistently comprised a major portion of the monthly ($n = 17$, $\bar{x} = 54\%$, $SD = 23$) and annual ($n = 7$, $\bar{x} = 51\%$, $SD = 21$) percentage of all species captured between 1991–1997. Similarly, sticklebacks comprised, on

TABLE 1. Changes in the percent composition of stickleback species and frequency of occurrence (in parentheses) of four stickleback species collected by the Ontario Ministry of Natural Resources at Thunder Bay, Ontario, during annual trawling from 1991–1997. The percent of sticklebacks captured as a percent of all species is shown. Total specimens refers to number of fish of all species captured. Sticklebacks were not identified to species level in 1991–1992.

Year	Percent Sticklebacks	Total Specimens	<i>Apeltes</i>	<i>Culaea</i>	<i>Gasterosteus</i>	<i>Pungitius</i>
1997	56.87	4201	1.59 (31.3)	0 (0)	0.58 (13.8)	97.82 (82.8)
1996	47.19	2871	14.21 (44.7)	4.49 (28.9)	4.12 (18.4)	77.17 (63.2)
1995	53.43	7855	11.05 (42.5)	6.52 (40.0)	9.34 (32.5)	73.08 (90.0)
1994	78.12	3834	7.89 (44.4)	1.37 (27.7)	0.96 (14.8)	89.76 (74.1)
1993	63.91	3702	2.31 (43.8)	1.42 (43.8)	3.99 (37.5)	92.27 (100)
1992	50.02	2575	?	?	?	?
1991	10.50	3695	?	?	?	?

TABLE 2. Changes in the percent composition of stickleback species captured at Mission Marsh, Thunder Bay, Ontario, during fall seining in 1984-1988, 1990-1992, 1995 and 1997-1998. The percent of stickleback species in the total catch is shown. Total specimens refers to number of fish of all species captured.

Year	Percent Sticklebacks	Total Specimens	<i>Apeltes</i>	<i>Culaea</i>	<i>Gasterosteus</i>	<i>Pungitius</i>
1998	(39.5)	38	93.3	0	6.7	0
1997	(51.6)	376	75.8	0	11.3	12.9
1995	(41.2)	68	96.4	0	0	3.6
1992	(43.4)	99	93.1	2.3	4.6	0
1991	(69.2)	26	100	0	0	0
1990	(42.6)	115	75.5	8.2	0	16.3
1988	(30.4)	25	42.8	0	0	57.1
1987	(20.0)	85	35.3	11.8	0	52.9
1986	(9.10)	22	0	0	0	100
1985	(5.80)	85	0	0	0	100
1984	(42.8)	23	0	100	0	0

average, 36% (SD = 19) of the seining sample during the years 1984–1998. Because sticklebacks constitute approximately 44% of the annual nearshore ichthyofauna, they are of numerical importance to the fish community of the Thunder Bay harbour and vicinity.

Apeltes has become the dominant species in nearshore areas of Mission Marsh (Table 2). Their frequency of occurrence has remained stable, but not increased dramatically in offshore trawls (Table 1). The abundance of *Culaea* has decreased, particularly in nearshore areas where it was once relatively common (Table 1). Seining records also demonstrate that the presence of *Pungitius* has decreased, particularly in nearshore locations (Table 2) while remaining abundant in offshore areas (Table 1). *Gasterosteus* has mainly increased in offshore waters (Table 1) and is only infrequently captured while seining.

The percent composition of each stickleback species has not remained similar during the trawling period ($P = 0.043$). The Newman-Keuls test identified that the means of *Apeltes*, *Culaea* and *Gasterosteus* have varied. The percent composition of seine captured *Culaea*, *Pungitius* and *Gasterosteus* also exhibited significant changes ($P < 0.01$) between years.

Calculated correlation coefficients do not provide evidence for significant ($P \leq 0.05$) negative or positive relationships between any of the four species. A very strong negative relationship exists between *Apeltes* and all three species using seine data and with *Culaea* and *Pungitius* using trawl data. *Gasterosteus* and *Pungitius* are negatively associated in seine hauls, but positively correlated based on trawl data. *Culaea* is positively associated with *Gasterosteus* and *Pungitius* using trawl data, but negatively with *Gasterosteus* in seine hauls.

Species Associations

Trawl captured *Gasterosteus* have been taken in association with (percent frequency in parentheses):

Pungitius (97), Rainbow Smelt (*Osmerus mordax*) (84), Mottled Sculpin (*Cottus bairdi*) (68), Fourspine Stickleback (64), Trout-perch (*Percopsis omiscomaycus*) (61), Brook Stickleback (32), Yellow Perch (*Perca flavescens*) (26) and Johnny Darter (*Etheostoma nigrum*) (26). *Gasterosteus* has been collected only occasionally in Mission Marsh during fall seining and, therefore, no associations can be elucidated.

Species captured in trawls with *Apeltes* include: *Pungitius* (96), Rainbow Smelt (88), Mottled Sculpin (79), Trout-perch (63), Brook Stickleback (55), Spottail Shiner (*Notropis hudsonius*) (47), Yellow Perch (45), Johnny Darter (39) and Threespine Stickleback (32). Seining records show that *Apeltes* has most frequently been captured with: Mottled Sculpin (100), Rainbow Smelt (64), Spottail Shiner (64), Yellow Perch (45) and Brook Stickleback (36).

Distribution in Lake Superior

Since its first appearance in Thunder Bay harbour in 1987, *Gasterosteus* has significantly increased its distribution within Lake Superior (Figure 1). *Gasterosteus* has occasionally been collected during annual trawling in pelagic U.S. waters of western Lake Superior although it has not been captured in Canadian waters (M. Hoff, United States Geological Service (USGS), personal communication). Eight specimens of *Gasterosteus* were collected in water intake tanks in Taconite Harbor (47°31'N, 90°55'W) with a single specimen collected in the Poplar River (47°38'N, 90°42'W), Minnesota, in 1994 (J. Hatch, James Ford Bell Museum, personal communication). One specimen was collected by seine from the Duluth-Superior harbour in Superior (46°69'N, 92°05'W), Wisconsin, in 1994 (D. Jensen, Minnesota Sea Grant, personal communication) and one specimen was captured in the Potato River (46°51'N, 89°23'W), Michigan, (UMMZ 232922), in 1996.

In 1995, four specimens of *Gasterosteus* were col-

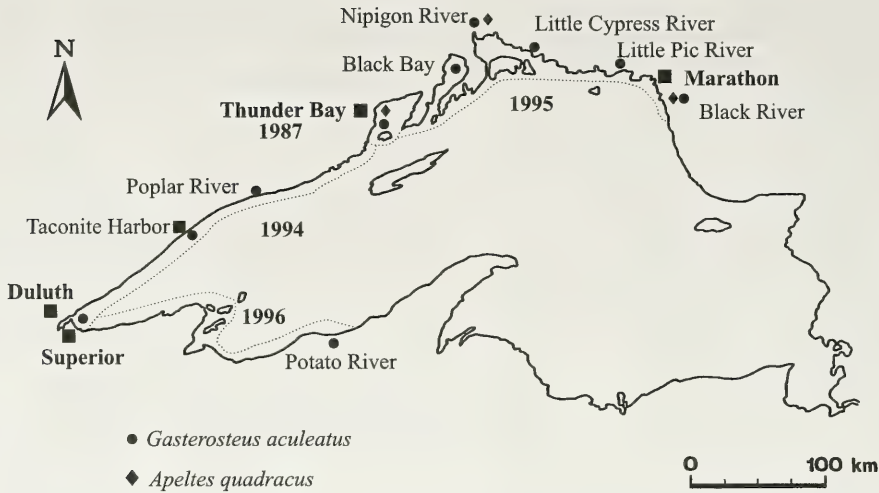


FIGURE 1. Location of collection of specimens of *Gasterosteus aculeatus* and *Apeltes quadracus* from Lake Superior. Map shows probable and known progression of *Gasterosteus* from 1987-1996.

lected in the Nipigon River (48°57'N, 88°14'W) (Lake Superior Programs Office 1996). An additional 22 individuals were collected by a biological consultant in the Black River (48°38'N, 86°16'W) and identified by us in 1995. We collected a specimen from Black Bay (48°40'N, 88°25'W) in 1996. One specimen was captured at the mouth of the Little Cypress River (48°56'N, 87°51'W) in 1997 (Stephenson 1998) and two more were captured in the Little Pic River (48°59'N, 86°45'W) and identified by us in 1998. The last three collections suggest that *Gasterosteus* is now well established between Thunder Bay and the Black River.

Since its introduction, *Apeltes* has been collected at only two additional Lake Superior locations. A single specimen was collected with the *Gasterosteus* specimens in the Black River in 1995. Three specimens were also collected from the Nipigon River in 1995 (Lake Superior Programs Office 1996). There are no reports of *Apeltes* from U.S. waters.

Discussion

While the relative abundance of all native species will exhibit a decrease in abundance due to the increase in frequency of the invading species, the rapid increase in *Apeltes*, especially in very nearshore areas, suggests it is displacing native sticklebacks at a rapid rate. In just over ten years, *Apeltes* has become the dominant stickleback species collected at Mission Marsh and is the only stickleback species collected on an annual basis (Table 2). Fall seining has most often captured *Apeltes* in or near areas of dense macrophyte growth.

Adult *Gasterosteus* collected by seine have most frequently been captured over sandy or rocky sub-

strates in areas where macrophyte growth is sparse or absent. We have most often seined juveniles in areas of sparse aquatic growth, although their habitat preference appears more variable than those of adults. The paucity of *Gasterosteus* in nearshore, shallow areas sampled by fall seining agrees with the trawling records indicating the preference of adult *Gasterosteus* for pelagic habitats. Trawling records suggest that *Gasterosteus* most closely associates with areas of sparse vegetation or open water habitats and a large percentage of trawl captured *Gasterosteus*, mainly adults, have been captured from the middle of rivers entering Thunder Bay harbour at depths of up to 13.0 m.

Wootton (1976) lists nearshore, weeded areas as the preferred habitat of both *Pungitius* and *Apeltes*. In the Thunder Bay area, however, *Pungitius* has become increasingly absent from these traditionally inhabited, nearshore areas and *Apeltes* is the common species. Although Worgan and FitzGerald (1981) explained the absence of *Apeltes* in some nearshore tidal pools as due to harassment from *Pungitius*, we do not see evidence for this in the Thunder Bay area. In recent seine collections, adult *Pungitius* are commonly associated with sand, gravel/rock or pelagic type habitats similar to those preferred by adult *Gasterosteus*.

Both *Gasterosteus* and *Apeltes* are preyed upon by several fish species, including salmonids (Wootton 1976; Campbell 1992). However, utilization of these two species as forage within any of the Great Lakes remains largely unknown. In contrast, *Pungitius* inhabiting open water areas of rivers and bays in Lake Superior is frequently consumed by pelagic predators such as Walleye (*Stizostedion vitreum*)

(Scott and Crossman 1973), Lake Trout (*Salvelinus namaycush*) (Griswold and Smith 1973) and several introduced salmonids (e.g., Johnson et al. 1995). Studies of the food habits of fish from river mouths of Thunder Bay harbour in 1987 did not reveal any utilization of *Gasterosteus* or *Apeltes* (Stephenson and Momot 1991). Since then, however, their increase in abundance in both seine and trawl hauls suggests that their importance in the diet of some piscivores may have increased.

Feeding experiments by Hoogland et al. (1956) suggest the possible impact of *Gasterosteus* on native food webs. Hoogland et al. (1956) found that both Northern Pike (*Esox lucius*) and European Perch (*Perca fluviatilis*) avoided consuming *Gasterosteus* whenever soft-rayed species or shorter-spined sticklebacks, such as *Pungitius*, were available. *Gasterosteus* and *Apeltes*, due to their deeper body size and larger spines, may be subject to less predation than native sticklebacks in Lake Superior. This may result in their becoming more abundant as native sticklebacks are selectively preyed upon by local fish species. McPhail and Lindsey (1986) blamed the loss of *Gasterosteus* populations on Vancouver Island due to nest predation by bullheads (*Ameiurus* sp.). Therefore, the spread of *Gasterosteus* may be slowed in areas where bullheads are present (e.g., southwestern Lake Superior).

Species Associations

Trawl captured *Gasterosteus* and *Apeltes* are highly associated with *Pungitius* in the Thunder Bay area. Therefore, *Pungitius* is the single species most liable to be affected by the introduction of these new species. This is due to close habitat association with probable diet overlap. Diet overlap is known to exist between *Pungitius* and *Gasterosteus* (Wootton 1976) and has been confirmed in the Thunder Bay area (Sinderly 1993). Stedman and Bowen (1985) predicted *Gasterosteus* might compete with *Pungitius* in Lake Michigan. In Lake Superior, a similar outcome is suggested by the apparent reduction in the abundance of *Pungitius* in seine captures and habitat overlap. Nelson and Paetz (1992) reported that the introduction of *Gasterosteus* to an inland lake decreased the numbers of *Culaea*, so this outcome is also possible. Although *Gasterosteus*, *Pungitius* and *Culaea* have coexisted in Lake Ontario for years, differences in habitat availability and species composition in Lake Superior may facilitate greater competition between these species.

Sinderly (1993) suggested that *Apeltes* would severely affect *Pungitius* abundance through diet overlap and possible competition for spawning habitat. In contrast, Delbeek and Williams (1988) reported little diet overlap between *Apeltes* and *Pungitius* in tidal pools due to prey size restrictions related to mouth size. Depending on the distribution and quantity of the food resource, however, competition could

be great. Any reduction in the abundance of *Culaea* or *Pungitius* through this competition, may cause diet shifts within piscivorous food webs whose consequences, at present, remain unknown.

Distribution in Lake Superior

Since *Gasterosteus* utilizes open water areas, this has allowed rapid dispersal into distant areas, and a dynamically rapid change in their distribution in Lake Superior. Stedman and Bowen (1985) noted the capture of *Gasterosteus* up to 14.0 km from shore at depths greater than 50.0 m. This differs substantially from habitats normally associated with this species in native areas (e.g., Wootton 1976). Their presence in off-shore areas, however, does not prove that *Gasterosteus* reached all new Lake Superior locations on its own. Anthropogenic activities, mainly inter- or intralake transport via ballast water transport, may have facilitated its arrival to some locations. Thus, *Gasterosteus* populations in the Marathon area may be the result of a second introduction from the lower Great Lakes or the marine environment. Alternative possibilities include natural movement from Thunder Bay or through the Sault St. Marie shipping locks from Lake Huron.

Apeltes, with few exceptions, is confined to very nearshore areas with dense aquatic vegetation. This is confirmed by their apparent absence in several rivers within and near the Thunder Bay Harbour lacking substantial macrophyte beds. Movement to the Nipigon and Black rivers remain perplexing because there is little in the way of suitable habitat between these areas and the Thunder Bay harbour. However, as *Apeltes* is presently unknown from the lower Great Lakes, a second invasion from the marine environment by ballast water does not seem a plausible explanation. We attribute movement to new Lake Superior locations to natural dispersal from Thunder Bay.

Trawl and seine records from Thunder Bay, as well as sampling in more distant areas, show that *Apeltes* and *Gasterosteus* have continued to spread along the Lake Superior shore. Despite a five-year sampling program, both species were not captured in the Nipigon area until 1995 (Lake Superior Programs Office 1996) suggesting that movement to this area may have been sudden. Their presence will almost certainly alter the food web relationships of native fish species, although it is impossible to state with the available data how detrimental these alterations will be to any species. Negative effects on native cyprinids, sculpins and darters, utilizing similar habitats and food resources and often closely associating with these two species, are possible and should be examined in greater detail. These effects may be observed through changes in abundance, habitat use, growth or diet. The negative correlations between the abundance of *Apeltes* and native sticklebacks suggest that negative interactions may be occurring and bears watching.

As with other non-intentionally introduced species, no practical methods exist for their elimination or control. Bait bucket introductions, by a public inexperienced in distinguishing sticklebacks, may introduce either or both of these species causing serious deleterious consequences to inland fisheries. This could be especially severe in areas where sticklebacks comprise the principal forage of important native game fish. Fisheries managers are urged to discourage the use of any Great Lakes caught fish as bait in inland waters, possibly halting the spread of these and other Great Lakes introduced species into new areas.

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Scavenging by Brown Bears, *Ursus arctos*, and Glaucous-winged Gulls, *Larus glaucescens*, on Adult Sockeye Salmon, *Oncorhynchus nerka*

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Adult Pacific salmon that have returned to spawn in streams are vulnerable to predation and are also susceptible to scavenging after death by animals such as bears and gulls. The distinction between predation and scavenging is important in furthering our understanding of the behavior of bears and gulls as well as the population dynamics of salmon. To understand better the role of these animals, we tagged freshly dead Sockeye Salmon, both spent and ripe, and recorded instances of scavenging on a small stream in southwestern Alaska. Both Brown Bears and Glaucous-winged Gulls scavenged about 20–30% of the salmon <1 day of tagging (1–2 days after death). With respect to gender, bears exhibited a preference for male salmon, gulls for females. With respect to spawning status, both showed a preference for ripe female salmon, a pattern that gulls also showed for male salmon. The proportion of salmon carcasses scavenged by bears increased to about 70% within 7 days of tagging, and many carcasses were partly scavenged on more than one occasion. Because of the high rate of bear scavenging and the tendency for this to mask scavenging by gulls, it was difficult to quantify gull scavenging accurately beyond 2–3 days. Bears tended to eat the cranial region of males and the bellies of females. The proportion of carcasses scavenged by bears varied greatly over the course of the spawning run, but was generally high early and late in the run when there were fewer live and dead salmon available.

Key Words: Brown Bear, *Ursus arctos*, Sockeye Salmon, *Oncorhynchus nerka*, Glaucous-winged Gulls, *Larus glaucescens*, carrion, nutrients, scavenging, Alaska.

Each summer and early fall many millions of anadromous Pacific salmon (*Oncorhynchus* spp.) complete the feeding stage of their life at sea and migrate to their natal streams to spawn and die. These salmon provide a massive influx of biomass and energy into nutrient-poor ecosystems, and the nutrients may be cycled through the aquatic and riparian ecosystem by various pathways (Kline et al. 1990, 1993; Bilby et al. 1996, 1998; Wipfli et al. 1998), including scavenging by terrestrial animals (Cederholm et al. 1989; Willson and Halupka 1995; Willson et al. 1998; Cederholm et al. 1999). Among the most visible vertebrates using the salmon resource in Alaska are Brown (*Ursus arctos*) and Black (*U. americanus*) bears. Bears tend to congregate around salmon streams and feed on live and dead salmon (e.g., Shuman 1950; Egbert and Stokes 1974; Frame 1974; Luque and Stokes 1976; Barnes 1989; Reinhart and Mattson 1989; Reimchen 1998). In some cases bears tend to kill male salmon and larger than average fish of both sexes (Gard 1971; Kononov and Shevlyakov 1979; Hanson 1992; Quinn and Kinnison 1999; Ruggerone et al. *in press*) but Frame (1974) reported that ripe (unspawned) females were more likely to be killed and consumed than males and spent females. It is clear that bears consume salmon, but some of these semelparous fishes might have been scavenged after death rather

than killed (Frame 1974). Such scavenging represents use of the salmon carcasses by the bears and so is important from the standpoint of bear nutrition (Hilderbrand et al. 1999) and transfer of nutrients from the stream to riparian ecosystems. However, dead salmon have lower energetic content than ripe, live salmon (Hendry and Berg *in press*). In particular, ripe (i.e., unspawned) females have a rich energy store in their gonads, which comprise about 15–20% of their weight (Hendry and Berg *in press*). Thus the nutritional value differs between those fish killed and scavenged.

Gulls, especially Glaucous-winged Gulls (*Larus glaucescens*), also make extensive use of adult salmon. Gulls peck at dead salmon but they can also attack live salmon and kill them or hasten their death. Both Mossman (1958) and Moyle (1966) found that female salmon were attacked more often than males, and they hypothesized that the gulls were primarily attracted to eggs. Mossman (1958) assumed that gull-pecked salmon in Hansen Creek, Alaska, had been killed, but the actual attacks were not documented. Mathisen (1962) also reported that some salmon were killed by gulls in the same creek, but attributed this to the unusual shallowness of the stream. Moyle (1966), on the other hand, observed the feeding behavior of gulls on a salmon stream in Prince William Sound, Alaska, and reported that

they scavenged dead salmon and especially those killed by bears, but did not actually kill salmon.

The distinction between scavenging and predation on salmon is important for several reasons. First, it enhances our understanding of the behavior of bears and gulls. Second, the nutritional content of salmon changes as they senesce, die and decompose (Hendry and Berg *in press*). Finally, scavenging does not affect the salmon population, but predation, especially on unspawned females, can affect the production of recruits for the next generation. Despite the common knowledge that bears both kill and scavenge salmon and the observations of gull-pecked carcasses, there has not been a quantified assessment of these behavior patterns. When one conducts a survey and finds salmon partially consumed by bears or pecked open by gulls, were they killed or scavenged after death?

Our objective was to estimate the magnitude and patterns of scavenging on Sockeye Salmon in a small stream in southwestern Alaska. We sought to test the following null hypotheses: (1) scavenging by bears and gulls is unbiased with respect to the sex and condition of the carcass, (2) scavenging is independent of the abundance of live salmon and carcasses in the stream. The predicted alternatives, based on qualitative observations, were that gulls would tend to scavenge ripe female salmon, especially immediately after death (e.g., fish that died by stranding before spawning), whereas bears would tend to consume male salmon (because they are larger) and would be less selective with respect to spawning condition and number of days post mortem. We also predicted that the probability of a carcass being scavenged would be inversely proportional to the availability of live and dead salmon in the creek.

Methods

Site Description

This study was conducted during the 1997 and 1998 spawning seasons (late July to mid-August) in Hansen Creek, a small (2 km) tributary of Lake Aleknagik in the Wood River system, Bristol Bay, Alaska. The stream was selected because there is documented predation by gulls (Mossman 1958; Mathisen 1962) and Brown Bears (Hanson 1992), and its small size (10 cm deep, 4 m wide and 2 km long; Marriott 1964) and clear water facilitated visual surveys. Additionally, this creek is not subjected to flooding, thus carcasses are not removed from the stream except by animals or our survey team. The riparian zone is a mixture of grasses and woody vegetation, primarily willow (*Salix* spp.), birch (*Betula papyrifera*) and White Spruce (*Picea glauca*) with an understory of grasses and shrubs (e.g., *Vaccinium* spp., *Empetrum* spp.).

Game trails became more numerous and distinct over the course of the salmon run, indicating move-

ment by bears along the stream. There were also discrete, obvious areas in the immediate vicinity of the stream where bears consumed fish, recognizable by the partially eaten carcasses, blood, and matted grass. Gulls tended to concentrate at the mouth of the stream, where there is a reach of exceptionally shallow water (4 cm deep) along the lake shore before the depth increases in Lake Aleknagik, the length of which can vary from 50–100 m depending on lake level. At the height of the run, however, large flocks of gulls were noted in other areas, especially in open tundra near spring-fed ponds about 1.5 km upstream from the mouth. In addition to Glaucous-winged Gulls, there were occasional sightings of smaller, less aggressive Mew Gulls, *Larus canus*, especially at the mouth of the creek. Our observations indicated that they largely scavenged eggs from the gravel and occasionally pecked at a carcass after it had been opened by a Glaucous-winged Gull. Because the Glaucous-winged Gulls were much more numerous and aggressive towards the salmon, we attributed the scavenging to them exclusively rather than to the Mew Gulls.

Survey Methods

A crew of 3–4 people walked the entire length of Hansen Creek each day during the salmon spawning seasons in 1997 and 1998, counting live male and female salmon. Dead fish were counted and the sex and probable cause of death (senescent, bear kill or gull kill) were recorded. After being counted, carcasses were removed from the stream area and thrown about 10 m upland to one side of the stream to avoid double-counting the next day. Hanson (1992) reported that the majority of kills in Hansen Creek were in the stream itself or within a few meters of the stream, therefore we did not systematically search upland areas for carcasses. These surveys provided us data on the temporal progression of the salmon run, and the magnitude and patterns of predation/scavenging.

To distinguish predation from scavenging, we applied a numbered metal tag to the lower jaw of a sample of dead fish. Only carcasses that exhibited no signs of consumption were used. Some of the carcasses (designated "spent") were salmon that had apparently died of senescence, as indicated by emaciated bellies (especially evident in females), scars from fights, frayed fins, fungus, etc. In addition, there were many salmon that had apparently stranded when migrating up particularly shallow parts of the stream. These salmon (designated "ripe") were readily distinguished from the spent fish because the females had generally not spawned and neither males nor females had frayed fins, wounds or signs of senescence. After the status (spent or ripe) and sex of the carcasses were recorded and they were tagged, they were measured for length from mid-eye to the

hypural plate (essentially, the end of the spinal column), weighed, and then left at the stream's edge where they had been found.

In 1997, 5–6 carcasses were tagged on each of 11 days between 20 July and 3 August. The carcasses were left out for 1 day to indicate the general magnitude of scavenging and only consumption by bears was recorded. Afterwards the carcasses were removed from the stream's vicinity. In 1998, 9–10 carcasses were tagged on each of 23 days from 23 July to 15 August. We not only increased the sample size compared to 1997 but we left carcasses out for longer periods of time, noting their condition and weight until they disappeared or were discarded. We also recorded evidence of gull wounds [see Mossman (1958) for an excellent description of the characteristics of a gull wound] as well as scavenging by bears. In both years we classified bear scavenging by part of the carcass eaten: brain (upper part of the head), belly (distinct bite with tissue removed from the ventral region), hump (tissue removed from the dorsal region), or body (all or most of the body, posterior to the head, eaten). We also noted carcasses that had been bitten (pronounced tooth-marks through the body) but with little or no tissue removed. These wound categories could be combined (e.g., "brain/body" was a valid characterization, as was "brain" or "body").

We categorized each carcass on the days following tagging as untouched, scavenged by bears (including missing carcasses) and (in 1998) scavenged by gulls. We used chi-square contingency tests to determine if the sex or condition (ripe or spent) of the carcass influenced its probability of being scavenged. For scavenged salmon, we recorded the parts of the body eaten (see above). In both 1997 and 1998 we analyzed the status of carcasses on the first day after tagging. In 1998 our sequential observations allowed us to also document multiple scavenging events. Finally, we recorded the status of the carcass when it was removed from the stream

area, or was judged missing because we could not find it on subsequent surveys.

Results

In 1997 we tagged 61 carcasses and observed them the following day. Of these, 17 (28%) were either scavenged by bears and left in the stream or were missing, presumably removed by bears (Table 1). Scavenging was unrelated to either sex or condition of fish ($\chi^2 = 3.70, df = 3, p > 0.25$). Evidence of gull scavenging was not recorded in 1997. In 1998 we expanded our study by tagging 218 carcasses and making repeated observations over a number of days. In 1998, the likelihood that a carcass was scavenged by a gull or bear, or went unscavenged after one day depended on both sex of the salmon and whether it was ripe or spent ($\chi^2 = 20.37, df = 6, p < 0.025$). Bears scavenged male salmon more often than females (34 vs. 20%) whereas gulls tended to scavenge female salmon (32 vs. 17%, Table 1). Bears scavenged male salmon regardless of their condition but scavenged ripe females more often than spent ones (30 vs. 16%). Gulls scavenged ripe fish of both sexes more often than spent ones (males: 22 vs. 13%, females: 48 vs. 27%).

The parts of the body eaten by bears varied between male and female carcasses ($\chi^2 = 18.75, df = 5, p < 0.005$, Table 2). The most striking differences were the proportion of male salmon that had their brain (top of head) eaten (26% vs. 8% for females) and females that had the belly region eaten (8% vs. 2% for males). Male salmon were slightly more likely to have the entire body (not including the brain) eaten (30% vs. 20%) and females were slightly more prone to be missing (57 % vs. 44%).

In 1998, we made a total of 657 observations on the status of 218 carcasses. Mean number of days (post-tagging) that carcasses were observed was 3.7 (SD = 2.1), including missing fish (mean = 2.8 d) and fish sequentially observed and eventually discarded

TABLE 1. Percentages of adult Sockeye Salmon carcasses scavenged one and seven days after death by Brown Bears (in 1997 and 1998) and gulls (data from 1998 only). Carcasses were categorized by sex and status (ripe or spent) at the time of death.

Sex	Status	Observations after 1 day				Observations after 7 days		
		1997 Bears		1998 Bears		Gulls %	1998	
		N	%	N	%		Bears %	Gulls %
Male	Ripe	25	16.0	60	35.0	21.7	80.0	20.0
	Spent	11	36.4	71	32.4	12.7	74.6	11.3
	Total	36	22.2	131	33.6	16.8	77.1	15.3
Female	Ripe	20	35.0	23	30.4	47.8	69.6	30.4
	Spent	4	25.0	64	15.6	26.6	65.6	25.0
	Total	25*	36.0	87	19.5	32.2	66.7	26.4
Total		61*	27.9	218	28.0	22.9	72.9	19.7

*In 1997, the status of one female was not recorded, but the carcass was included in calculations of overall scavenging.

TABLE 2. Body parts of 110 male and 67 female tagged Sockeye Salmon scavenged by Brown Bears on Hansen Creek, Alaska (1997 and 1998 data combined). Categories are not mutually exclusive (e.g., both brain and hump could be eaten) and multiple scavenging events on different days (e.g., brain on one day, missing two days later) are counted. Percentages refer to the proportion of all scavenging events by bears in which those body parts were eaten. Bite refers to a wound with no tissue consumed.

Body part consumed	% of male salmon	% of female salmon
bite	19.7	14.7
brain	25.8	8.0
hump	2.3	0
belly	1.5	8.0
body	29.6	20.0
missing	43.9	57.3
number of scavenging events	132	75

(mean = 4.5 d). Repeated observations of carcasses suggested they were not only scavenged on the day after they were tagged (i.e., 1–2 days after they died) but some were scavenged several days later. About half (51%) of the carcasses were untouched by either gulls or bears after one day but almost all (93%) were eventually subjected to some form of scavenging (Table 1; Figure 1). Most carcasses were eventually scavenged by bears (77% of males and 67% of

females) and the rate of gull scavenging appeared to decline more rapidly than that of bears. However, in many cases a carcass that had been bear scavenged (e.g., removed or body eaten) could not be subsequently classified as gull scavenged.

In 80 cases the first evidence of bear scavenging was the carcass's disappearance from the stream while in 80 cases the carcass was scavenged in place. Most carcasses were so heavily consumed, when first classified as scavenged, that we discarded them and retrieved the tags, but 24 bear-scavenged carcasses were left in the stream for further observations. Subsequent (secondary) scavenging by bears was indicated in 23 cases. Nine carcasses were missing, 6 were largely consumed and we retrieved the tags, and 8 were left on site. Of the latter, 7 had tertiary scavenging (3 disappeared and 4 were further consumed).

The numbers of live fish in the stream and the total number of dead recorded each day (Figure 2a) were compared with the daily proportion of carcasses scavenged (Figure 2b). The availability of live salmon showed an approximately normal distribution and dead salmon followed that distribution, peaking about a week later. Scavenging ranged from about 20–40% of the carcasses present on any day. There was no clear pattern to the daily variation, except that the proportion of carcasses scavenged seemed to rise and fall several times, reaching the

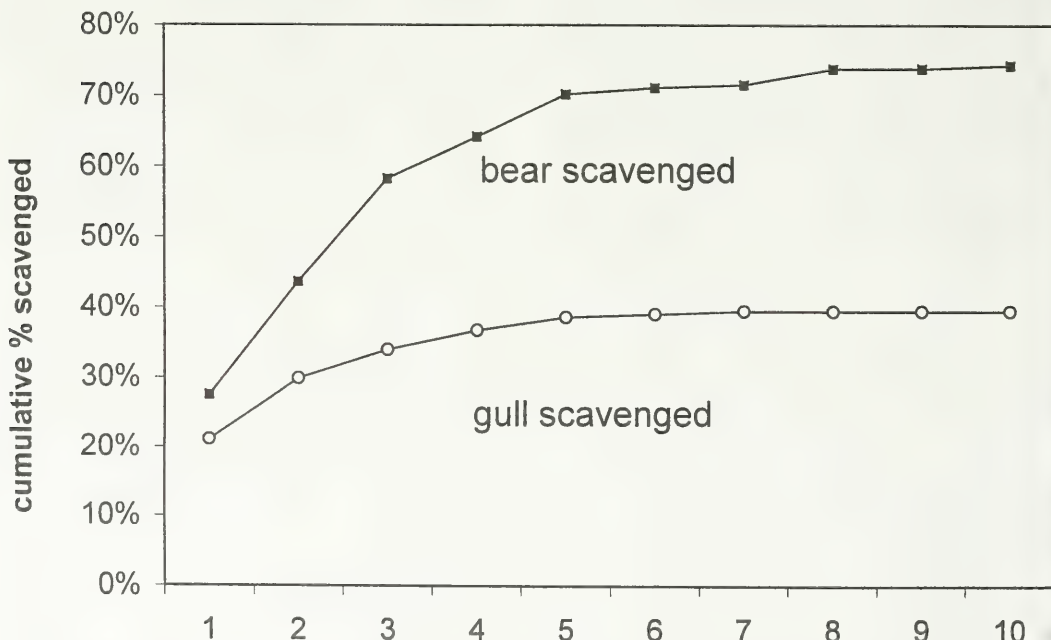


FIGURE 1. Cumulative proportions of the 218 dead Sockeye Salmon left in Hansen Creek that were scavenged by gulls or bears on successive days after tagging. Note that the number of fish available to be scavenged by gulls diminished over time as bears consumed or removed fish from the study area.

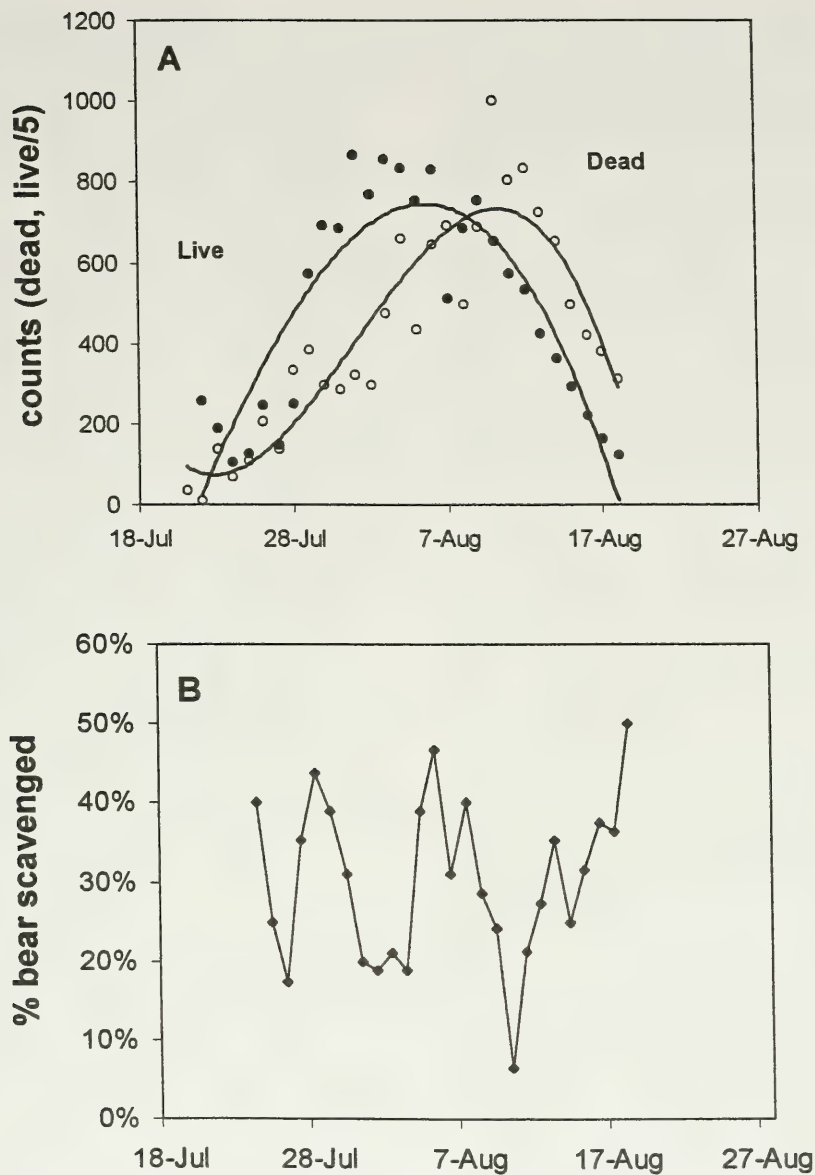


FIGURE 2. A) The numbers of live (filled circles) and newly dead (open circles) Sockeye Salmon recorded each day during 1998 as a resource for predation or scavenging. Curves represent polynomial trendlines (live: $r^2 = 0.81$, dead: $r^2 = 0.85$). B) The proportion of tagged carcasses in the stream that was scavenged by bears on each day in 1998.

lowest level around the date of peak abundance of live and dead salmon and rising towards the end of the run, when live and dead salmon became progressively more scarce.

Discussion

Gulls tended to scavenge female salmon and especially ripe ones, typically attacking the belly and

vent regions, as well as the eyes and gills. Mossman (1958) observed salmon remains on Hansen Creek and concluded that gulls were killing salmon and especially females. Moyle (1966) observed gulls feeding on salmon in a spawning stream, and noted that gulls were not killing salmon, but rather were feeding on salmon killed by bears or carcasses that gulls dragged ashore. Both authors noted that gulls

tended to attack females and hypothesized that gulls are primarily attracted to eggs. Our evidence that gulls tended to scavenge ripe females more than spent ones supports this hypothesis. Male salmon were also scavenged by gulls, although only about half as often as females. Male salmon not only lacked the eggs that may attract gulls to females, but the thicker skin of males may be less penetrable by gulls than that of females. The holes in the body made by gulls showed evidence of repeated chiseling as though only by considerable effort could they break the skin. Gulls scavenged about 20% of the fish after one day but only 40% of the fish were recorded as gull-scavenged over the course of the study, unlike bears that more often scavenged fish that were greater than one day old. It should be noted that gull-scavenged carcasses could still be recorded as bear-scavenged on subsequent dates, but once the carcass was either removed by a bear or the body consumed, subsequent gull wounds could not be detected. Thus in the absence of bears, greater scavenging by gulls might have been noted.

The scavenging patterns of bears differed from those of gulls. Bears scavenged males more often than females but this may have been largely due to their limited use of spent females. This is consistent with evidence that bears tend to eat the bellies of females (Hanson 1992; Ruggerone et al. *in press*, and our own observations). The most common bear-scavenging event for male and female carcasses was removal from the stream (which could not be distinguished from complete consumption) whereas many of the other fish had their bodies eaten. About half of the carcasses were untouched one day after being tagged. Most (73%) were eventually scavenged by bears, but the probability of a carcass being scavenged on a given day declined as it became less fresh. Therefore, on a cumulative basis, the longer a carcass was in the stream, the more likely it was to be scavenged by a bear. Many instances of sequential scavenging were also noted, though we have no way of knowing whether it was the same or different bears that scavenged the carcasses. The tendency of bears to remove carcasses from the stream has implications for the transfer of nutrients to the riparian zone. The bears not only consume salmon and transfer nutrients to the terrestrial environment through their waste products, but they sometimes drop partially consumed carcasses on land. Based on general observations and the status of a few tagged carcasses left in the forest, such carcasses are reduced to skeletons by insects (especially larval flies) in about a week unless bears scavenge them.

In addition to their tendency to scavenge, highly selective feeding by bears was also evidenced. They tended to eat the bellies of females, the brains of males, and sometimes bit the fish but ate no tissue. This selectivity probably resulted from the great

density and availability of salmon and alternative food sources. Signs of Caribou (*Rangifer tarandus*) kill were noted in the vicinity of the stream, and bear scat frequently contained berries and other plant material. If food were scarcer, bears might eat more of salmon carcasses, and we have observed extensive consumption of salmon on other streams in south-western Alaska.

We hypothesized that the frequency of scavenging would be inversely proportional to the number of live and dead salmon available to the bears but data were equivocal. Scavenging levels fluctuated in the early and middle parts of the run, but seemed to go from low to high as the density of salmon went from the peak to the end of the run (Figure 2). Nevertheless, there was considerable scavenging even during the peak of the salmon run, indicating that abundant, available live and fresh dead salmon do not preclude scavenging.

In addition to the implications of our results for the ecology of bears and gulls, they indicate that surveys of dead salmon along streams have two sources of bias with respect to bear predation. First, some salmon that die of senescence are bitten post-mortem (73% were eventually scavenged in 1998, 28% at least one day post-tagging). This would tend to inflate the apparent level of "predation" by bears. On the other hand, some scavenged salmon (and presumably some killed as well) were removed from the vicinity of the stream and were "missing". After one day, 34 carcasses (16%) were scavenged in place and 27 (12%) were removed from the stream. At the end of the observation period, 72 (33%) had been scavenged in place and 88 (40%) were removed from the stream. Thus surveys might underestimate total salmon abundance and bear consumption if many carcasses were removed. Given the large number of live salmon in this shallow, clear stream, the levels of scavenging seem surprisingly high. This may, in part, be due to the fact that the survey method reduced access by bears and gulls to untagged dead by daily removing them. Patterns of scavenging and removal of salmon from streams by bears may vary among streams, years, and bears. Our results should thus not be taken to indicate absolute levels of scavenging and carcass removal. Rather, they show that these activities can occur frequently and can affect estimates of salmon abundance and predation levels. The probability of such errors increases with the length of time between surveys.

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Status of the Northern Riffleshell, *Epioblasma torulosa rangiana* (Bivalvia: Unionidae), in Ontario and Canada†

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The Northern Riffleshell, *Epioblasma torulosa rangiana*, is a small, colourful, sexually-dimorphic freshwater mussel that lives in highly-oxygenated riffle areas of rivers and streams. Its host fish in Canada is unknown. It has suffered dramatic declines in North America over the past century, with the current distribution representing a range reduction of more than 95%. It was listed as Endangered under the U.S. Endangered Species Act in 1993. Causes of its decline include the Zebra Mussel, *Dreissena polymorpha*, which has infested a large portion of the subspecies' former range, and agricultural impacts. All rivers where the subspecies still occurs are located in areas of intense agriculture and forestry, which makes them susceptible to siltation and runoff of agricultural chemicals. The distribution of *E. t. rangiana* in Canada is now restricted to the middle reaches of the Sydenham and Ausable rivers in southwestern Ontario. The Sydenham River population is one of only three populations in North America that still show evidence of successful reproduction, hence the preservation of this population is important for the global survival of the subspecies. It is predicted that *E. t. rangiana* will become globally extinct within 10 years unless measures are taken soon to protect it.

Key Words: Northern Riffleshell, *Epioblasma torulosa rangiana*, Unionidae, freshwater mussels, endangered species, COSEWIC, Great Lakes, Ontario.

In 1994, the Committee On the Status of Endangered Wildlife In Canada (COSEWIC) expanded its mandate to include invertebrates. The Mollusc Working Group of the Lepidoptera and Mollusca Subcommittee was formed in 1995 to develop a national list of Canadian mollusc species at risk and prepare status reports on them. The Committee On the Status of Species At Risk in Ontario (COSSARO) was also established in 1995, and it recently began to consider aquatic species for listing, including invertebrates. In response to these initiatives, Metcalfe-Smith et al. (1998a) examined recent and historical data on the distributions of the freshwater mussels (Unionidae) of southern Ontario and prepared a prioritized list of the most imperiled species. This region was chosen for study because it historically supported 75% of Canada's 53 species of freshwater mussels. Nine species, most having current sub-jurisdictional ranks of S1 (NHIC 1997)*, were proposed for national status designation by COSEWIC. It was recommended that six other species known only from historical records (ranked SH) be given a lower priority for listing, because they may already be extinct and beyond help. The Northern Riffleshell fell into the latter group.

In 1997 and 1998, Metcalfe-Smith et al. (1998b, 1999) conducted intensive surveys at 66 sites on the Grand, Thames, Sydenham, Ausable and Maitland Rivers of southwestern Ontario to determine the conservation status of their mussel communities. During this work, five species that were thought to be extirpated from Ontario (and Canada) were found alive, including *Epioblasma torulosa rangiana*. The Northern Riffleshell is the only species or subspecies of freshwater mussel in Canada that is currently listed as federally endangered in the United States. As such, it is appropriate that *E. t. rangiana* should be one of the first species of freshwater mussel to be officially designated as a Canadian species at risk.

Description

According to Clake (1981), *Epioblasma torulosa rangiana* is "Unmistakable among Canadian unionids because of its extreme and unique sexual dimorphism and small size." Stansbery et al. (1982)* describes the shell as small to medium-sized, sub-compressed to subinflated, and solid. Males are irregularly ovate, with a wide, shallow sulcus just anterior to the posterior ridge. Females are obovate, greatly expanded post-ventrally with the expansion very broadly rounded, and transversely swollen after about the third year of growth. In both sexes, the periostracum is brownish yellow to yellowish green with diffuse, fine green rays. The umbonal structure is finely double-looped. The nacre is white, the pseu-

†Endangered status assigned by COSEWIC 19 April 1999.

*See Documents Cited section



FIGURE 1. Live specimens of *Epioblasma torulosa rangiana* found in the Sydenham River near Florence, Ontario in August, 1998. Specimen in the middle of the photograph is a female; specimen at the lower right is a juvenile; other specimens are males.

docardinal teeth are small, and the lateral teeth are fairly short and moderately thick. Clarke (1981) adds that the beaks are elevated above the hinge line and moderately excavated. Mature individuals have been reported to vary in shell length from 45 to 76 mm (Clarke 1981; Cummings and Mayer 1992; USFWS 1994), although surveys in southwestern Ontario in 1997-1998 produced specimens up to 90 mm long. Figure 1 shows five living specimens of *E. t. rangiana* from the Sydenham River. Three of the five animals are males (the largest is 59 mm in length); the smaller specimen in the middle of the photograph is a young female (35 mm); and the smallest specimen (17 mm) is a juvenile of indeterminate sex.

Epioblasma torulosa rangiana was originally described by Lea in 1837 and named after the French malacologist Sander Rang (USFWS 1994). The type locality for the subspecies is the Ohio River near Cincinnati, and Yellow Creek of the Mahoning River near Poland, Ohio. Three distinct subspecies of *Epioblasma torulosa* are generally recognized: *E. t. torulosa*, *E. t. rangiana*, and *E. t. gubernaculum* (Turgeon et al. 1988), but many consider *E. t. rangiana* to be the headwater form of *E. t. torulosa* (USFWS 1994). Neither *E. t. torulosa* nor *E. t. gubernaculum* have ever been found in Canada, and both are presumed extinct (Williams et al. 1993).

Distribution

The Northern Riffleshell was historically known from Alabama, Illinois, Indiana, Kentucky, Michigan, Ohio, Pennsylvania, Tennessee (questionable records), West Virginia, and Ontario (USFWS 1993*); see inset, Figure 2A. Although the sub-

species has never been found in New York, it is believed to have occurred there at one time since it was found in two rivers only a few kilometres from the New York border (Strayer and Jirka 1997). It was found throughout the Ohio River drainage in rivers such as the Ohio, Allegheny, Scioto, Kanawha, Little Kanawha, Licking, Kentucky, Wabash, White, Vermilion, Mississinewa, Tippecanoe, Tennessee, Green and Salt (USFWS 1993*). In the Great Lakes drainage, it was found in the Maumee River basin and tributaries to western Lake Erie such as the Huron River and the River Raisin (USFWS 1993*). It also occurred in southern Michigan in the Black River and Elk Creek tributaries of the St. Clair River (Hoeh and Trdan 1985). In Canada, it was historically known from western Lake Erie and the Detroit River (museum records), Lake St. Clair (La Rocque and Oughton 1937) and the Sydenham River (Clarke 1973) in southwestern Ontario. A previously unknown population was discovered in the Ausable River, a tributary to lower Lake Huron, in 1998 (Metcalf-Smith et al. 1999).

Figure 2A illustrates the historical distribution of *E. t. rangiana* in Ontario (and Canada) based on occurrence records from the National Water Research Institute's Lower Great Lakes Unionid Database. The database and its data sources are described in detail in Metcalf-Smith et al. (1998a). At present, the database consists of over 5000 records for 40 species of mussels collected from the Canadian waters of the lower Great Lakes drainage basin between 1860 and 1998. A total of 14 historical records for *E. t. rangiana* were available from the holdings of the Canadian Museum of Nature (CMN), the Ohio State

University Museum of Biological Diversity (OSUM) and the University of Michigan Museum of Zoology (UMMZ), as well as the personal records of Carol B. Stein (retired from the OSUM) and the private collections of Herbert D. Athearn, Emeritus, Tennessee Academy of Science and Michael J. Oldham, Natural Heritage Information Centre, Ontario Ministry of Natural Resources.

Protection

Canada does not have federal endangered species legislation at this time. However, Ontario is one of several provinces that have stand-alone Endangered Species Acts (Aniskowicz 1997). Species classified as provincially Endangered, and their habitats, are protected from willful destruction under these acts, but there is currently no protection for Threatened or Vulnerable species. In Ontario, the Provincial Policy Statement under Section 3 of The Planning Act prohibits development and site alteration in the habitats of Threatened and Endangered species. The Northern Riffleshell is currently being considered for Endangered status in Ontario by the Committee On the Status of Species At Risk in Ontario (COS-SARO) and, if approved, would receive provincial protection. Other mechanisms for protecting mussel habitat in Ontario include the Ontario Lakes and Rivers Improvement Act, which prohibits the impoundment or diversion of a watercourse if it would cause siltation; and the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food and Rural Affairs, which is designed to reduce the erosion of agricultural lands. Stream-side development in Ontario is managed through flood plain regulations enforced by local conservation authorities. Most land along the reach of the Sydenham River where *E. t. rangiana* presently occurs is privately owned and in agricultural use. Two small properties, the 7 ha Shetland Conservation Area and the 20 ha Mosa Township forest, are publicly owned (Muriel Andreae, St. Clair Region Conservation Authority, personal communication, March 1998). The Ausable-Bayfield Conservation Authority (ABCA) owns a number of properties totalling 1830 ha throughout the Ausable basin (K. Vader, ABCA, personal communication, March 1999).

The federal Fisheries Act may represent the most important legislation protecting the habitat of *E. t. rangiana* in Canada. Under this Act, freshwater mussels are considered to be shellfish, which are included in the definition of "fish" and are therefore afforded protection in theory. In practice, application of the Fisheries Act tends to focus on the protection of habitats that support recreational or commercial fisheries. As *E. t. rangiana* presently occurs in rivers that support recreational fisheries, its habitat should be indirectly protected by the Fisheries Act.

In the United States, *E. t. rangiana* is listed as Federally Endangered and is protected under the Endangered Species Act (USFWS 1994). This Act provides for possible land acquisition, and requires that recovery actions be carried out for all listed species. The Northern Riffleshell is also listed as endangered in Ohio (Ohio DNR 1997*), Illinois, Indiana, Kentucky and Michigan (TNC 1997*) and Proposed Endangered in Pennsylvania, and is therefore afforded protection in these states. In Michigan, for example, the destruction or possession of any species listed as endangered or threatened in the state is prohibited under the Natural Resources Environmental Protection Act (Michigan DNR 1998*).

Population Sizes and Trends

Epioblasma torulosa rangiana is a rare subspecies (Clarke 1981; USFWS 1993*). Although occasionally abundant, it is usually a minor component of the unionid community (Strayer and Jirka 1997). Ahlstrom (1930, as cited in USFWS 1994) once remarked that the Northern Riffleshell "...was everywhere, but not common..." in the vicinity of the Bass Islands in western Lake Erie. The only density estimate available for this mussel is 0.09 individuals/m² from a site on the upper Allegheny River in northwestern Pennsylvania that supports 17 species of mussels, including the endangered Clubshell (*Pleurobema clava*) and Northern Riffleshell (G. F. Zimmerman, EnviroScience, Inc., Cuyahoga Falls, Ohio, personal communication, March 1999). The site was described as having a low to moderate diversity and density of unionids for this river. A population of *E. t. rangiana* described only as "sizable" was relocated from the Black River, Michigan, in 1988 as part of a rescue effort to protect this and other rare species from an impending dredging operation (Trdan and Hoeh 1993). Only 12 of the nearly 8000 mussels collected over a 10-day period were *E. t. rangiana*, and a total of 118 specimens of this subspecies were eventually captured after 22 more days of sampling. As the size of the area searched was not provided, density estimates could not be derived.

The Northern Riffleshell has suffered dramatic declines in North America over the past century, with the current distribution representing a range reduction of more than 95% (USFWS 1993*). Detailed information on the remaining known populations in the United States is presented in USFWS (1994), and summarized here. Populations in the Allegheny River and French Creek, Pennsylvania are apparently the largest that remain. In French Creek, the subspecies is abundant in several reaches where hundreds of shells may be found in muskrat middens over a short distance. In the Allegheny River, populations are more variable with an overall known bro-

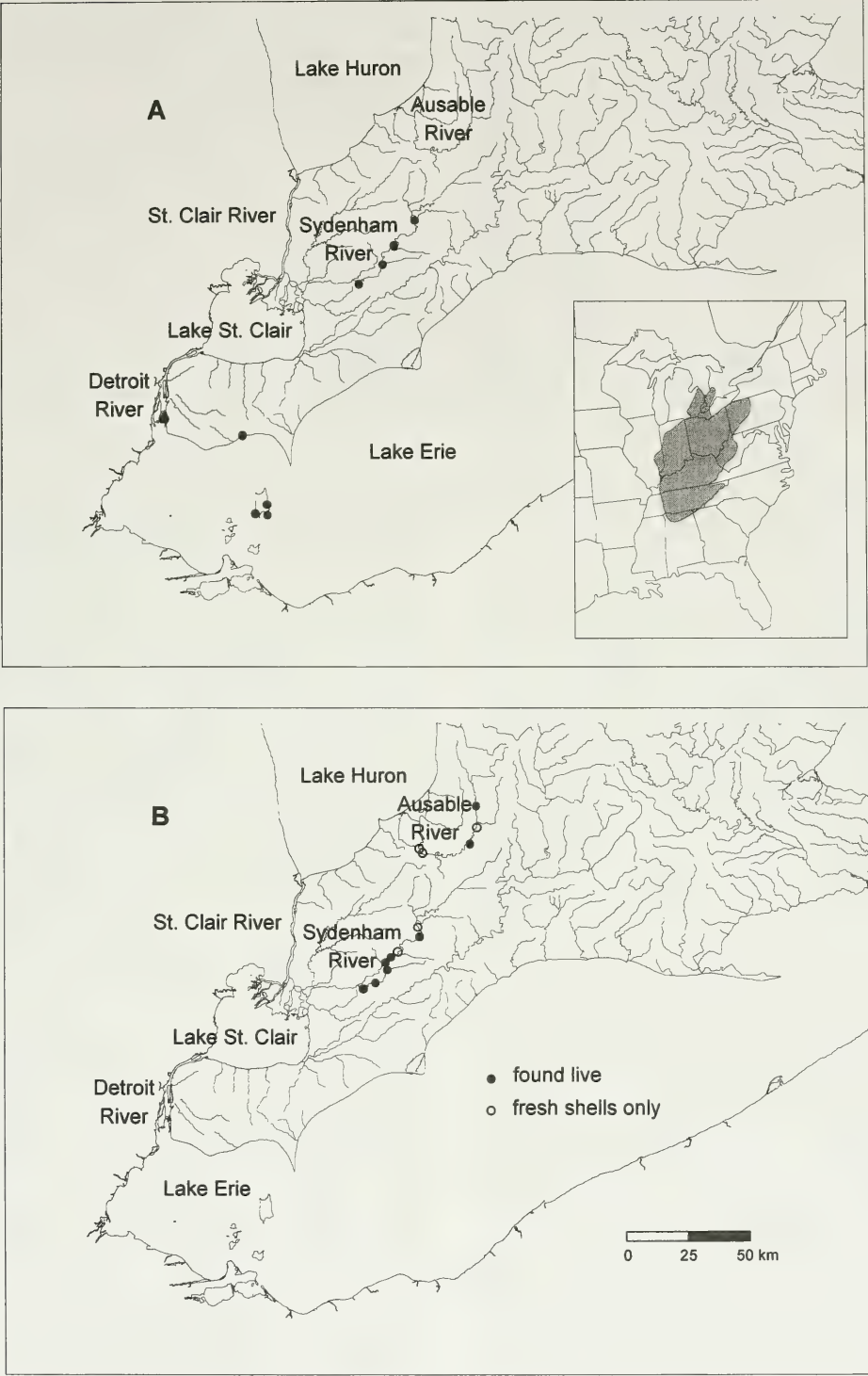


FIGURE 2. Distribution of *Epioblasma torulosa rangiana* in Ontario. A. Historical distribution (inset shows historical North American distribution). B. Presumed current distribution, based on the results of 1997-1998 surveys.

ken range of 128 km. In contrast, the presence of *E. t. rangiana* in LeBouef Creek, Pennsylvania, and the Green River, Kentucky in recent years is indicated by dead shells only. In Fish Creek in the Maumee River drainage of Ohio, living and fresh dead individuals have been reported only rarely, and the most recent surveys have not confirmed its continued existence. The subspecies was once common in Big Darby Creek, Ohio, but is now represented by a declining population in a 24 to 32 km stretch of the creek. It was recently found alive in the Elk and Oak Rivers, West Virginia (G. T. Watters, Ohio State University, personal communication, March 1998); however, additional surveys are required to determine the status of these populations.

The Northern Riffleshell has been collected only sporadically in the Canadian waters of the lower Great Lakes drainage basin over the past century. It was first collected in Lake Erie at Kingsville, Ontario, in 1890 by J. T. McQueen (CMN Catalogue # CMNML002450). Three other occurrences of the subspecies were recorded from Pelee Island in Lake Erie between 1934 and 1960, but there have been no subsequent records. It was also reported from the Canadian waters of the Detroit River at Bois Blanc Island by Bryant Walker in 1934 (UMMZ Catalogue # 906617), but has not been reported since. It may be reasonably assumed that *E. t. rangiana*, like so many other native mussel species, has been eradicated from Lake Erie, Lake St. Clair, and the Huron-Erie corridor by the Zebra Mussel, *Dreissena polymorpha* (see section on limiting factors).

Sydenham River

The Northern Riffleshell was first collected from the Sydenham River in 1963 by H. D. Athearn near the town of Shetland (Clarke 1973). Between 1965 and 1973, live specimens and/or fresh shells were collected from three sites near Alvinston, Florence and Dawn Mills (C. B. Stein, personal communication, September 1997). Clarke (1973) conducted the first extensive survey of the Sydenham River in 1971, visiting 11 sites. He did not find *E. t. rangiana*, but it should be noted that he used a smaller sampling effort than previous collectors (Clarke averaged 1h per site, whereas Athearn conducted a 4h survey and Stein searched for up to 6h). Similar results were reported by Mackie and Topping (1988), who surveyed 20 sites on the Sydenham River in 1985 using a sampling effort of 1h per site. They were unable to locate live specimens of *E. t. rangiana* or three other rare species, and concluded that these species may no longer be present in the Sydenham River. This alarming news prompted a further survey of 16 sites on the river in 1991 by Clarke (1992). He spent between 0.4 and 8.0 person-hours (p-h) at each site, and although he found many more live species than Mackie and Topping (1988), he did not find any trace of *E. t. rangiana*.

Based on these findings, the subspecies was assigned a sub-jurisdictional conservation status rank of SH (no verified occurrences in the past 20 years) in Ontario by the Natural Heritage Information Centre (NHIC 1997*).

With the discovery of live *E. t. rangiana* in the Sydenham River in 1997, the subspecies was confirmed extant in Ontario and downlisted from SH to S1 (extremely rare) by the NHIC (D. A. Sutherland, Natural Heritage Information Centre, Ontario Ministry of Natural Resources, personal communication, April 1999). Metcalfe-Smith et al. (1998b, 1999) surveyed 66 sites on the Grand, Thames, Sydenham, Ausable and Maitland Rivers in 1997 and 1998 to assess the current conservation status of rare species of freshwater mussels in southwestern Ontario. They used the timed-search sampling method because of its documented effectiveness for detecting rare species (Strayer et al. 1997), and an intensive sampling effort of 4.5 p-h/site. Sites that were known to support these species in the past were targeted, including the four sites on the Sydenham River where *E. t. rangiana* had been found between 1963 and 1973. According to the results of these surveys, the current range of *E. t. rangiana* in the Sydenham River extends over a 50 km stretch of the river between Alvinston and Dawn Mills (see Figure 2B). A total of 26 live animals numbering 2-11 individuals/site were encountered at six of seven sites surveyed within this reach. Fresh shells were found at the seventh site, and at another site 5 km upstream of the reach. As no live animals or shells were found at four other sites surveyed above Alvinston, the upstream limit of the subspecies appears to have been defined. The downstream limit is likely at Dawn Mills, as there is little gradient (and thus no riffle habitat) below this point and water levels fluctuate with the levels in Lake St. Clair. Five sites were also surveyed on the North Sydenham River (Bear Creek) in 1997-1998. The Northern Riffleshell was not found at any of these sites, nor had it been in the past.

It appears that the current distribution of *E. t. rangiana* in the Sydenham River is essentially the same as the historical distribution (compare Figures 2A and 2B); however, there is evidence to suggest that abundance has declined. Sites surveyed at Florence and Alvinston in 1997 and Dawn Mills in 1998 had been surveyed several decades earlier by Stein using similar survey techniques and sampling efforts, thus allowing an assessment of changes in abundance over time. In 1965, Stein collected 23 live specimens of *E. t. rangiana* from the Florence site (6 p-h of sampling effort), representing nearly 30% of all live mussels encountered. In 1973, she collected 32 fresh whole shells from a muskrat midden at the same site (3 p-h of sampling effort), but did not find any live animals. In contrast, only two individuals (less than 2% of the 124 live unionids encountered) were found

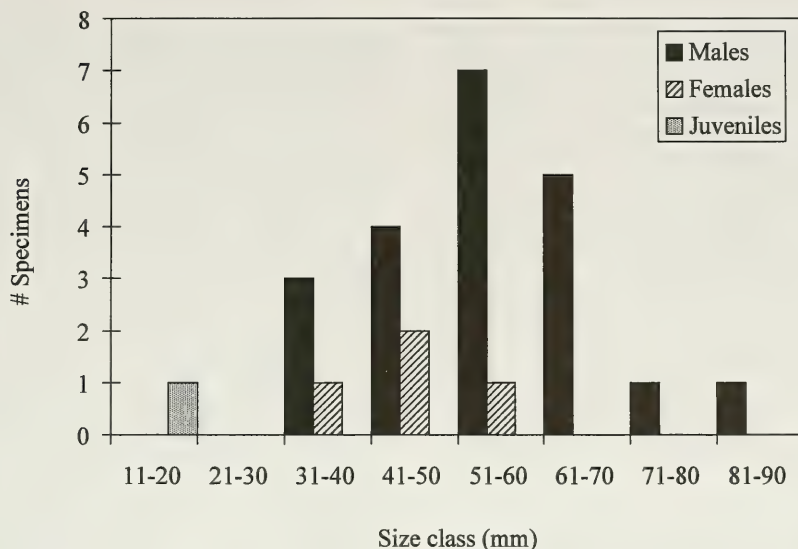


FIGURE 3. Size class distributions for live *E. t. rangiana* found in the Sydenham River in 1997–1998.

at this site in 1997. Capture rates were 3.8 specimens/h in 1965 vs. 0.4 specimens/h in 1997, suggesting a decline in abundance of nearly 90% over the past 32 years at this site. The fact that only 12 weathered valves and one fresh shell were found at the site in 1997, whereas 21 and 32 fresh whole shells were found in 1965 and 1973, respectively, provides further evidence of a declining population. Stein collected one live animal and no shells from the Dawn Mills site in 1973, using 3 p-h of sampling effort. In 1998, two live specimens (and no shells) were found during 12 p-h of searching (six people for two hours); thus, the capture rate in 1973 was twice that in 1997 (0.33 vs. 0.17 specimens/h, respectively). Stein also collected one fresh half shell from the site at Alvinston in 1967. One fresh whole shell was collected from the same site 30 years later. Although a decline in the numbers of *E. t. rangiana* over time has only been documented for two sites on the Sydenham River, the paucity of live animals (maximum 11/site) and fresh shells (no more than a single valve or whole shell at any site) found in 1997–1998, as well as the complete absence of the subspecies from the collections of Mackie and Topping (1988) and Clarke (1992), suggest that the entire Sydenham River population has suffered a decline in abundance.

Using the 1997–1998 data, sex ratios and sex-specific size class distributions were examined for the Sydenham River population. The M:F (male:female) sex ratio for live animals was heavily skewed towards males at 21:4 (or 81% male), while the sex ratio for shells was more balanced at 14:13 (or 52%

male). Although the Sydenham River population shows signs of recent recruitment, with a juvenile as small as 17 mm found (Figure 3), the apparent lack of females is disconcerting. There is little information in the literature on normal sex ratios for any mussel species. Trdan and Hoeh (1993) studied the demographics of *E. torulosa rangiana* and *E. triquetra* in the nearby Black and Clinton rivers, in southeastern Michigan. A M:F sex ratio of 59%:41% was reported for *E. t. rangiana* in the Black River, which is impacted by agriculture, based on a sample size of 114 live specimens. In the much cleaner Clinton River, a nearly even M:F sex ratio of 52%:48% was observed for 799 live *E. triquetra*. These results suggest that females of *E. t. rangiana* may be unnaturally scarce in the Sydenham River.

Shell lengths of the 21 live males collected from the Sydenham River ranged from 35 to 90 mm (mean = 56 mm). The four females ranged in length from 35 to 54 mm (mean = 46 mm). Although total lengths reported in the literature vary, lengths greater than 76 mm had not been previously reported. The only Canadian publication (Clarke 1981) states that mature males are 45 mm and mature females 50 mm in length. In the Black River, Michigan, *E. t. rangiana* ranged in length from 36 to 68 mm (sexes combined), with an average length of 52 mm for males and 48 mm for females (Trdan and Hoeh 1993). Thus, females in the Sydenham River appear to be average in size, or a little small, whereas the size distribution of males clearly shows a tendency towards very large animals — well beyond sizes reported in the literature. The size class distribution

for males (Figure 3) indicates the presence of several year classes, but with a bias towards larger, older animals. The co-occurrence of old, large males and fewer, smaller females implies that males may have a better survival rate than females. As females are considerably smaller than males for many species of mussels, including the related Purple Catpaw, *Epioblasma obliquata obliquata* (M. A. Hoggarth, Otterbein College, Westerville, Ohio, personal communication, March 1999), and as females of some species do not live as long as males (e.g., the Mudpuppy Mussel, *Simpsonia ambigua*; M. C. Barnhart, Southwest Missouri State University, Springfield, Missouri, personal communication, March 1999), further studies would be needed to determine if the sex ratios and sizes of Northern Riffleshells in the Sydenham River are within normal parameters.

Ausable River

In 1998, a previously unknown population of *E. t. rangiana* was discovered in the Ausable River of the lower Lake Huron drainage (Metcalf-Smith et al. 1999). Eight sites were surveyed, and one live specimen was found at each of two sites in the middle reaches of the river near Nairn and Brinsley, respectively (Figure 2B). Fresh shells were found at these and three other sites near Arkona and Ailsa Craig, whereas weathered shells were found at all sites except one in the headwaters near Exeter. Weathered shells were most numerous at the sites near Arkona (34 of 59 weathered shells found at all sites), where they may have accumulated from sites further upstream. These results suggest that the range of *E. t. rangiana* in the Ausable River once covered a distance of approximately 55 km between Brinsley and Arkona. As the gradient flattens out below Arkona, it is unlikely that the lower portion of the river would have offered suitable riffle habitat for the Northern Riffleshell. Although many more live specimens were found in the Sydenham River (26 from 17 sites) than the Ausable River (2 from 8 sites), the reverse was true for shells (27 from the Sydenham and 95 from the Ausable). These comparisons suggest that: (i) the population of *E. t. rangiana* in the Ausable River may once have been larger than that in the Sydenham River, and (ii) the Ausable River population has declined in recent years to a level far below that in the Sydenham River. With so few live animals in evidence, the sustainability of the Ausable River population appears doubtful.

Habitat

It is widely accepted that the Northern Riffleshell lives mainly in highly oxygenated riffle areas of rivers (Ortmann 1919, as cited in USFWS 1993*; Clarke 1981; Cummings and Mayer 1992). The preferred substrate has been described as rocky and sandy bottoms (Clarke 1981), and as firmly packed

sand and fine to coarse gravel (Cummings and Mayer 1992). Recent observations in the Sydenham River confirmed these claims: all live animals encountered in 1997 and 1998 were found in stable substrates of coarse sand to fine gravel in shallow (generally < 30 cm), flowing waters in or near riffles. This subspecies is purported to occur in streams of various sizes, from small to medium (Ortmann 1919, as cited in USFWS 1993*; Stansbery et al. 1982*) and medium to large (Cummings and Mayer 1992). Its existence in the western basin of Lake Erie was apparently due to sufficient wave action to produce continuously moving water (USFWS 1994). There is no information available on the thermal tolerance of *E. t. rangiana*; however, water temperatures at sites where live specimens were found in the Sydenham and Ausable rivers in August of 1997 and 1998 ranged from 18–27°C. The extent of preferred habitat in the 50 km stretch of the Sydenham River where *E. t. rangiana* still occurs is unknown. As this reach has a relatively low gradient of about 0.4 m/km (DERM 1965*), riffle habitat would likely constitute only a small proportion of the total habitat.

General Biology

Although the specific biology of *E. t. rangiana* is not well known, general unionid biology is applicable (USFWS 1994). The Northern Riffleshell is a small to medium-sized, sexually dimorphic mussel that tends to live for 15 years or more (USFWS 1993*). It is not known at what age reproductive maturity is reached or when it ends (USFWS 1993*). Although hermaphroditic individuals have been encountered for many unionid species (Kat 1983), this condition has not been detected in *E. t. rangiana* (USFWS 1994). During spawning, males release sperm into the water and females living downstream take in the sperm via their incurrent siphons. Fertilization success in mussels may be related to population density, with a threshold density required for successful reproduction to occur (Downing et al. 1993). Female mussels brood their young from the egg to the larval stage in their gills, using the posterior portions of their outer gills as marsupia (USFWS 1993*). *Epioblasma torulosa rangiana* is a long term brooder (bradytic), with a gravid period extending from late summer to the following spring (Ortmann 1919, as cited in USFWS 1993*; Clarke 1981). The shell of the female is distended along the posterior ventral margin to accommodate the expanded gill pouches, a feature that is called a marsupial swelling. When the larvae, or glochidia, are ready to be released, the female displays a spongy, pure white mantle lining that can be seen from several metres away and may function to attract fish hosts (USFWS 1994). Once expelled into the water by the female, the glochidia must attach to the fins of an appropriate fish host in order to complete their metamorpho-

sis. Transformation requires a period of 27 to 33 days, after which the juvenile mussels detach from their host and fall to the substrate to complete their development into free-living adults.

The glochidia of *E. t. rangiana* are semicircular, have a straight hinge line without hooks (Clarke 1981), and are 230 μm high and 250 μm long (Hoggarth 1993). Hoggarth (1993) demonstrated that functional morphology in glochidia appears to be correlated with rarity in the Unionidae. Glochidia of rare species tend to be morphologically depressed (valve height minus valve length equals zero or less), an adaptation for holding on tightly to the host at the expense of ensuring initial attachment. The majority of such glochidia attach to the fins, rather than the gills, of their host fish. This strategy apparently reduces the rate of successful parasitic encounters, thereby limiting recruitment. Hoggarth (1993) suggested that this factor "...may be responsible for much of the continuing decline in a population once numbers of breeding adults reaches a critically low level". He also noted that members of the genus *Epioblasma* provide the best example of this effect, as most are currently listed as federally endangered in the United States.

Until recently, the glochidial fish hosts for *E. t. rangiana* were completely unknown. However, Watters (1996)* has now identified four species of fish that serve as hosts in the United States: the Bluebreast Darter (*Etheostoma caeruleum*), Banded Darter (*Etheostoma zonale*), Banded Sculpin (*Cottus caroliniae*) and Brown Trout (*Salmo trutta*). None of these species are native to Ontario; thus, the endemic fish host(s) for Canadian populations of the subspecies remain unknown. Brown Trout were introduced into Ontario in 1913 (Scott and Crossman 1973), and may now serve as hosts. Because darters and sculpins are frequently associated with *Epioblasma* species (G. T. Watters, Ohio State University, personal communication, June 1998), data on the distributions of these fishes in the Sydenham and Ausable rivers were obtained from the Royal Ontario Museum and the Ontario Ministry of Natural Resources' Ontario Fisheries Information System for comparison with the distribution of *E. t. rangiana* in these rivers.

Ten species of darters have been reported from the Sydenham and/or Ausable rivers. Three of these species, the Greenside Darter (*Etheostoma blennioides*), Rainbow Darter (*Etheostoma caeruleum*), and Logperch (*Percina caprodes*), are unlikely candidates as they did not serve as hosts in laboratory tests (Watters 1996*). Three other species, the Least Darter (*Etheostoma microperca*), Johnny Darter (*Etheostoma nigrum*) and Blackside Darter (*Percina maculata*), are common to both watersheds and are therefore the most likely hosts. The Eastern Sand Darter (*Ammocrypta pellucida*) is

an interesting possibility. This darter has suffered severe population declines (Holm and Mandrak 1996), and is now listed as "Threatened" in Canada. It historically inhabited the Sydenham and Ausable rivers, but has apparently disappeared from the latter. It may be more than a coincidence that the current ranges of the Eastern Sand Darter and Northern Riffleshell in the Sydenham River roughly correspond (compare Figure 2 in Holm and Mandrak (1996) with Figure 2b in this paper), and that the Northern Riffleshell is following the Eastern Darter's path to extirpation in the Ausable River. The Mottled Sculpin (*Cottus bairdi*) and/or the Slimy Sculpin (*Cottus cognatus*) may have served as hosts in the past, but are likely now restricted to colder headwater regions where *E. t. rangiana* does not occur.

The Northern Riffleshell, like all freshwater mussels, is a filter feeder. Although the exact food preferences of the adult form are unknown, they are probably similar to those of other freshwater mussels; i.e., suspended organic particles such as detritus, bacteria and algae (TNC 1986*). Although they are capable of moving short distances, mussels are basically sessile organisms that are highly dependent on their host fish for dispersal during the glochidial stage.

Limiting Factors

Siltation, impoundments, in-stream sand and gravel mining, pollutants from municipal, industrial and agricultural sources, and the invasion of the Zebra Mussel have been identified as threats to the continued existence of *E. t. rangiana* (USFWS 1994). Access to suitable fish hosts may also be a factor, but it cannot be assessed for Canadian populations until the host species have been identified. Members of the genus *Epioblasma* are particularly sensitive to river regulation because they are riffle/run inhabitants that cannot tolerate other substrates. The Sydenham and Ausable rivers, which are the last refugia for this subspecies in Ontario and Canada, are not regulated because of their small size and low gradient. Thus, dams and reservoirs do not limit the distribution of this mussel in Canada.

Much of *E. t. rangiana*'s range in the United States and Canada falls within areas of intensive agriculture and forestry, subjecting the animal to pesticide- and fertilizer-laden runoff as well as siltation (USFWS 1994). Siltation can bury and smother mussels and/or interfere with feeding (Dennis 1984). Because *E. t. rangiana* has never been subjected to toxicity testing, its sensitivity to specific environmental contaminants is not known. However, domestic sewage, effluents from paper mills, tanneries, chemical industries and steel mills, acid mine runoff, heavy metals and pesticides have all been implicated in the destruction of mussel communities in general (Bogan 1993).

Siltation is probably the most immediate threat to *E. t. rangiana* in the Sydenham River, although eutrophication and pesticide inputs may also be significant factors. Land use in the watershed is predominantly agricultural, i.e., cash crop, pasture and woodlot (Muriel Andreae, St. Clair Region Conservation Authority, personal communication, March 1998). Twenty years ago, Clarke (1978) found the river to be largely unpolluted. By 1985, Mackie and Topping (1988) reported that an extensive artificial drainage network had been created over the years to drain the predominantly agricultural land adjacent to the river. They observed diminishing dissolved oxygen concentrations with increasing distance downstream, and attributed the significant loss of mussel diversity (20 of the 33 species previously reported from the system were not found alive in 1985) to changing water and substrate quality. More recently, Clarke (1992) noted that all of the species missing from the Sydenham River (including *E. torulosa rangiana* and *Epioblasma triquetra*) during his 1991 survey were partly or wholly riffle-dwelling species, and that most of the riffles were now covered with silt. Thus, he stated that "...a correlation between loss of those species, and apparent loss of clean riffle habitat, appears to exist". Metcalfe-Smith et al. (1998b, 1999) found that water clarity (measured as maximum depth at which the stream-bed was clearly visible) was poor in 1997-1998, averaging 23 cm for all sites sampled and 18 cm for the sites where *E. t. rangiana* was found alive, indicating heavy suspended sediment loadings to the system.

Agriculture is the primary land use in the Ausable River watershed, with over 50% of the area being used for row crops (corn and beans) and only 13% remaining forested (ABCA 1995). Livestock farming is also intensive, particularly in the upper watershed. Water quality is generally poor because of runoff from agricultural lands, septic system seepage, and pollution from manure. About 60% of the soils are artificially drained, which decreases base flows in the river and contributes to flooding during storm events. Sediment loadings are high. The natural course of the lower portion of the river was destroyed in the late 1800s, when it was diverted in two places to alleviate flooding. Water clarity averaged about 30 cm in the Ausable River in 1997-1998 (20-25 cm at the sites where *E. t. rangiana* still occurs), which was slightly better than in the Sydenham. A combination of high suspended sediment loads and pollution are likely the limiting factors for *E. t. rangiana* in the Ausable River, acting either directly or indirectly through impacts on their host fish.

The recent invasion of the Great Lakes by the Zebra Mussel led to catastrophic declines of native mussels in infested waters, and severely contracted

the range of *E. t. rangiana* in Canada. Zebra Mussels have decimated the native mussel communities of Lake St. Clair (Nalepa et al. 1996) and western Lake Erie (Schloesser and Nalepa 1994). Heavy infestations of Zebra Mussels have been known to kill unionids in less than one year. This was clearly illustrated in 1988, when 118 live specimens of *E. t. rangiana* were transferred from the Black River, Michigan to a large corral constructed on the bottom of the Detroit River near Detroit, Michigan to protect the population from a dredging operation (Trdan and Hoeh 1993). The caged mussels were monitored every spring with no evidence of Zebra Mussels observed until the summer of 1992, at which time all of the relocated individuals were found dead and heavily encrusted with Zebra Mussels. The Detroit River population was previously considered to be one of the few remaining reproducing populations of this subspecies, and it appears to have been eliminated. It has been recently suggested that coastal wetlands around Lake Erie may serve as refuges from the Zebra Mussel for many species of unionids (Nichols and Wilcox 1997). However, the soft, silt-clay sediments in these areas do not meet the substrate requirements of shoal-dwelling species such as *E. t. rangiana*. Populations of the Northern Riffleshell in the Sydenham and Ausable rivers are not significantly at risk of exposure to Zebra Mussels, because these rivers have no reservoirs that could support a permanent colony of these pests should they ever be introduced.

Predation by Muskrats, *Ondatra zibethicus*, is a potential limiting factor for some mussel species. For example, Muskrat predation appeared to be a major cause of death for the endangered Clubshell (*Pleurobema clava*) in the Tippecanoe River, Indiana (USFWS 1994). Historically, Muskrat predation probably had little, if any, effect on healthy mussel populations; however, similar levels of predation today pose a serious threat to endangered species already reduced to low densities and isolated locations (Neves and Odum 1989). In the U.S., the removal of Muskrats has been undertaken at some sites identified as important refugia for endangered mussels (W. A. Tolin, U.S. Fish and Wildlife Service, personal communication, February 1998). Although it is difficult to assess the impact of Muskrat predation on Ontario populations of *E. t. rangiana* without further investigation, some anecdotal information exists. During her 1973 visit to the Sydenham River, C. B. Stein (personal communication, September 1997) reported finding a "...midden heap consisting mainly of fine fresh *Epioblasma torulosa rangiana* shells!" — 32 fresh whole shells in all. Although abundance of prey species in shell middens is generally related to the relative abundance of species at the site, there is some evidence for the selection of "mid-sized" specimens or species

[defined as 45-65 mm in shell length according to Convey et al. (1989) and Neves and Odom (1989); 70-120 mm according to Watters (1993-1994)] such as *E. t. rangiana*. Regardless of whether *E. t. rangiana* is preferred by Muskrats or not, it is conceivable that muskrat predation could be a contributing factor to the decline in abundance of the subspecies in the Sydenham River. At the present low densities, any level of predation could jeopardize its continued existence.

Special Significance of the Species

Epioblasma torulosa rangiana is one of the last remaining members of a near-extinct genus (Hoggarth 1993). Without intervention, it will undoubtedly follow the same path. All members of the genus *Epioblasma* are riffle-dwellers, whose habitat is being relentlessly destroyed. The Sydenham River population of *E. t. rangiana* is one of only three remaining populations in North America that show evidence of recruitment (as noted earlier, the other two are in Pennsylvania). As such, its preservation is important for the global survival of the subspecies. The Sydenham and Ausable river populations are the northern-most populations of *E. t. rangiana* in North America, and may represent unique genetic variation for the species (Barr 1996*). The time for recovery action is now; three related species, *E. t. torulosa*, *E. turgidula* and *E. florentina florentina* were federally listed in the United States in 1976, but by the time a recovery plan was prepared for them in 1985 (USFWS 1985), all were presumed extinct.

Evaluation

Epioblasma torulosa rangiana has suffered dramatic declines in North America over the past century, with the current distribution representing a range reduction of more than 95%. It was listed as "Endangered" under the federal Endangered Species Act in the United States in 1993, and is globally ranked as G2T2. Its current sub-national ranks in the United States are SX in Illinois and Indiana, and S1 in all other jurisdictions (TNC 1997*; K.S. Cummings, Illinois Natural History Survey, personal communication, May 1998). Until recently, the subspecies was thought to be extirpated from Canada. However, remnant populations were discovered in the Sydenham and Ausable rivers in southwestern Ontario in 1997-1998, and it was subsequently downlisted from SH to S1 in Ontario. The historical range of the Northern Riffleshell in Canada once included western Lake Erie, Lake St. Clair and the Detroit River. The presence of Zebra Mussels throughout the Great Lakes precludes the recovery of *E. t. rangiana* throughout much of its original range.

The Sydenham River population of *E. t. rangiana*

occupies a 50-km stretch of the middle reaches of the river. The population appears to be continuous, as most sites surveyed within this stretch produced live animals. Densities ranged from ~1 to 11 live individuals/4.5 p-h of sampling effort, which would be considered low to moderate according to density categories set by The Nature Conservancy (TNC 1996*) for this subspecies (low to moderate = 1-2 live individuals/2-3 survey hours). Live specimens found in 1997-1998 were of a wide range of shell sizes, which suggests that recruitment is still occurring. As the sex ratio was strongly biased towards males, however, continued reproductive success is far from certain. Comparisons with historical data suggest that abundance may have declined by as much as 90% over the past three decades. The Sydenham River population of *E. t. rangiana* was once believed to be the healthiest extant population in North America (Clarke 1978). It may still be stronger than the majority of existing occurrences in North America (G.T. Watters, Ohio State University, personal communication, March 1998). The once abundant Ausable River population of *E. t. rangiana* has been reduced in recent years to only a few scattered individuals, with no signs of reproduction. The future of the Ausable River population therefore appears bleak.

Members of the genus *Epioblasma* have suffered an extraordinarily high rate of extinctions over the years (USFWS 1985). All members "...are riverine and typically found in streams which are shallow with sandy-gravel substrate with rapid currents" (Stansbery 1971, as cited in USFWS 1985), which means that they are extremely vulnerable to impoundments, siltation and pollution. It is also possible that their fish host(s) have been adversely affected by some of these perturbations. As the fish host(s) for in *E. t. rangiana* in Canada are not known, the decline of host fish populations cannot be evaluated as a possible factor in the decline of the subspecies in this country. All rivers in Canada and the United States where *E. t. rangiana* is found are located in areas of intense agriculture and forestry, and are susceptible to runoff and siltation. Agricultural chemicals and siltation are likely the most significant threats to the continued existence of this subspecies in North America, notwithstanding the impact of the Zebra Mussel.

According to Biggins (1992*), *E. t. rangiana* faces global extinction within the next decade unless measures are taken soon to protect it. As Ontario harbours one of only three known reproducing populations in North America, it is recommended that the Northern Riffleshell be classified as Endangered both in Ontario and Canada. This manuscript is based on the reports to COSEWIC and COSSARO, but has been updated to incorporate new data collected in 1998.

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Occurrence of Beluga, *Delphinapterus leucas*, in Summer off Northeastern Coats Island, Northwest Territories

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Gaston, Anthony J. 2000. Occurrence of Beluga, *Delphinapterus leucas*, in summer off northeastern Coats Island, Northwest Territories. *Canadian Field-Naturalist* 114(2): 236–240.

Observations from a site close to Cape Pembroke, Coats Island, Northwest Territories, during the summers of 1984–1998, revealed the occurrence of substantial numbers of Beluga close inshore in years when shore-fast ice cleared out by early July. The frequency of days on which Belugas were observed peaked between 20 June – 5 July, while highest mean numbers occurred on 17–28 June and 7–11 July. Most movements observed were towards the east, raising questions concerning the origin and destination of these animals.

Key Words: Beluga, *Delphinapterus leucas*, population, movements, Coats Island, Hudson Bay, Northwest Territories.

The Beluga, or White Whale, *Delphinapterus leucas*, occurs in summer throughout open water areas of the Canadian Arctic (Banfield 1974). Hudson Bay supports a large population, divided into summering stocks in Northern Hudson Bay, West Hudson Bay, South Hudson Bay, James Bay and eastern Hudson Bay (“Eastmain”) (Finley et al. 1982; Reeves and Mitchell 1987; Richard et al. 1990; Richard 1993). Most of the animals from eastern Hudson Bay and many from the other stocks are believed to winter in Hudson Strait, including some, at least, from the largest stock, in western Hudson Bay (Finley et al. 1982; Richard 1993). The course and timing of movements between summering and wintering areas is very poorly known (Reeves and Mitchell 1987; Richard 1993).

The Canadian Wildlife Service (CWS) has maintained a camp on Coats Island, northern Hudson Bay each summer since 1984 to study breeding seabirds. Field personnel have kept daily records of marine mammals observed throughout their period of residency. General observations on the birds and marine mammals sighted at Coats Island up to 1996 were described by Gaston and Ouellet (1997). I report here on the seasonal occurrence, movements and behaviour of Beluga along the coast adjacent to the CWS camp.

Methods

Observation periods varied from 14 days (1984) to 97 days (1995), with early August being the period of most frequent coverage. During June, land-fast ice occurred along the north coast of the island in some years, so that open water was too far away to allow observations of Belugas. The first date on which open water was present within < 1 km of the observation site ranged from 6 June in 1990 to 25 June in 1988 and 1992. Observations were made from the start of the ice-free period to at least 17 August in

nine years (1988, 1990–1992, 1994–1998; see Gaston and Ouellet [1997] for details). Numbers of days of occurrence and mean numbers seen are based only on those years, but selected observations in other years are also referred to.

Most Beluga sightings were made during observations of birds, or while watching from the vicinity of camp. Observation blinds for birds were situated 20–50 m above sea level near the tip of a small promontory, 4 km west of Cape Pembroke, the northeast tip of Coats Island (Figure 1). In addition, a good view out to sea was obtained from the camp, situated at 80 m above sea level and 300 m from shore, on the same promontory. No dedicated watches were made for marine mammals, but 3–6 observers were in the field for approximately 8 h/day, customarily scanning the adjacent sea from time to time. When Beluga were observed close to camp the sea was customarily scanned for others. A telescope was kept at the camp for incidental observations of birds and mammals offshore. Weather conditions, especially visibility, and sea state must have considerably affected the detection of Belugas. Days when viewing conditions were particularly poor are indicted in Appendix 1.

Counts or estimates of numbers seen were recorded. On some days, it was evident that passage occurred for long periods and our watches covered only a small fraction of the day. Hence our estimates of Belugas passing the camp were probably very minimal.

The behaviour of Belugas seen off Coats Island could be divided into two categories: travelling (animals swimming steadily with a more-or-less constant heading, surfacing regularly), and feeding/socializing (animals milling about, diving for longer periods, no uniform direction, or proceeding steadily, then reversing). Not all records could be categorized, either because behaviour was not noted, or because

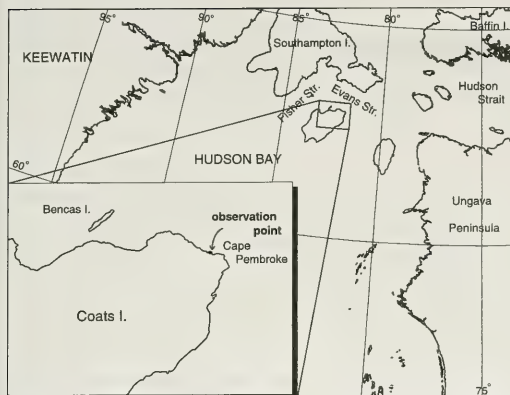


FIGURE 1. Map of Hudson Bay, showing the location of the camp and features mentioned in the text.

poor sea conditions prevented discrimination. Notes were kept of group sizes and composition of adults (white) and immatures (grey), but this information was not always recorded.

Results

Timing. Earliest sightings were on 15 June (1991, 1997) and latest on 20 August 1993. Belugas were

observed on 25% of open water days in June ($n = 182$), 13% in July ($n = 279$) and 1% in August ($n = 223$). The proportion of open-water days on which Belugas were seen peaked between 21 June and 4 July (Figure 2), when Belugas were seen on 34% of days ($n = 126$). They were seen on only 17 days after 10 July (4%, $n = 429$).

Numbers. The highest June total was 1802, in 1998, and the highest July total 500, in 1994 (Appendix 1). The largest number recorded in a single day was 500, on 26 June 1998. Mean numbers sighted on days when at least one was seen ranged from 1-300, with averages of > 100 recorded for 17-19 June, 23 and 25 June, 7, 8 and 10 July (Figure 3).

Behaviour. Beluga that were travelling were usually in distinct groups of 3-10 animals, spaced 50-250 m apart, but moving within a relatively narrow corridor that passed 50-500 m from the tip of the camp promontory. Groups of more than five animals usually contained both adults and immatures: solitary adults were sometimes seen, but solitary immatures were rarely observed. Several records after mid-July involved single females with small calves ($< \text{half body length}$). Foraging animals also tended to be in distinct pods of similar size, but some aggregations of up to 200 formed in the cove to the east of camp, where they frequently milled about and vocal-

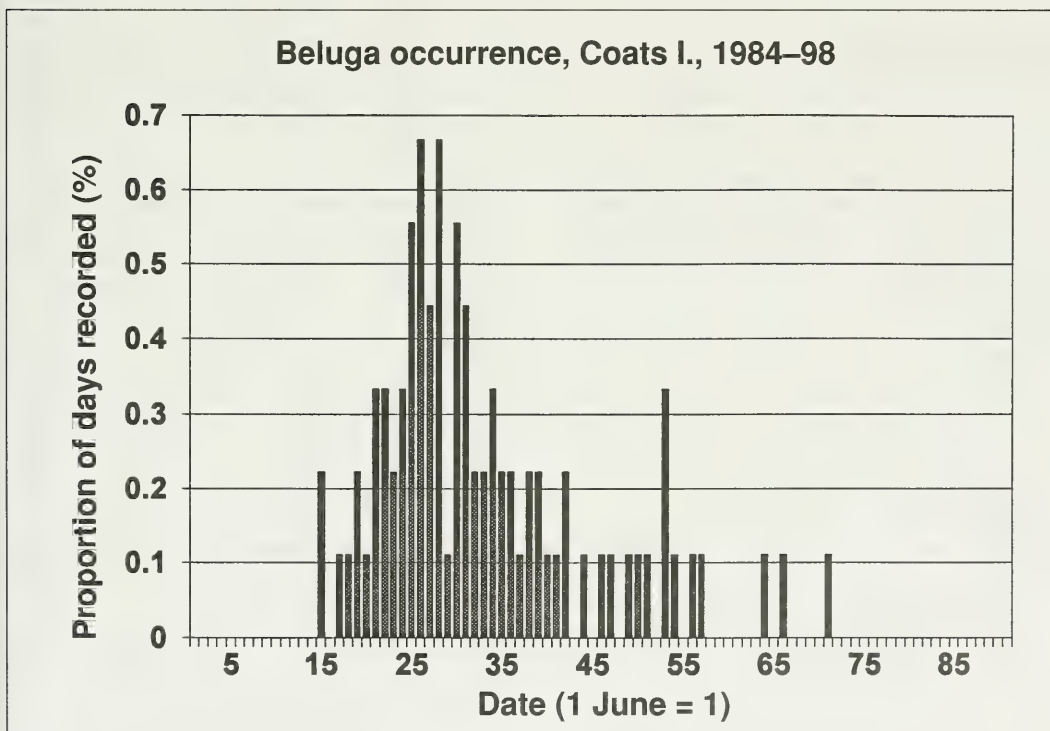


FIGURE 2. The frequency of occurrence of Belugas off the CWS camp on Coats Island during 1984-1998. Occurrence is expressed as the proportion of days when observers were present on which Belugas were noted.

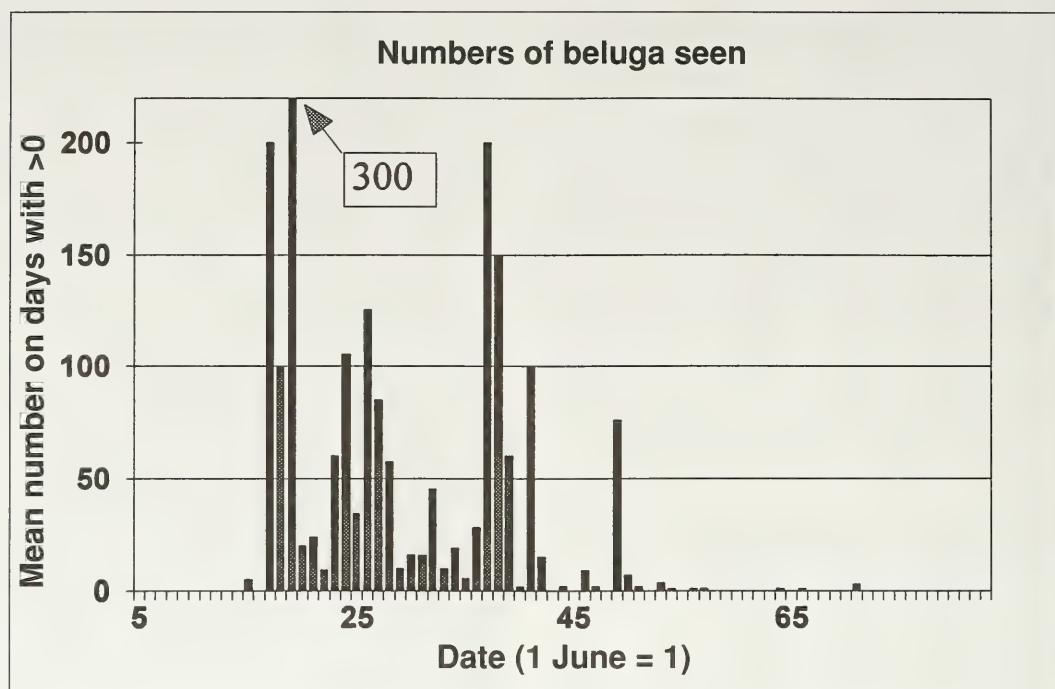


FIGURE 3. Mean numbers of Belugas sighted from the CWS camp on days when at least one was seen.

ized (this could be heard sometimes from land: in 1995 we also had a hydrophone).

Large numbers of travelling Belugas were seen only in 1994, 1995 and 1998. Most noteworthy were movements of several hundreds on 21 June 1994, 26–28 June 1995, and 17–19 June 1998. On the last two occasions numbers of Beluga passing the camp exceeded 100/h for at least 2–3 h. All were heading east, which was true of most travelling Belugas. The only strong movements seen in July were of 50 heading east on 4 and 6 July 1997.

Discussion

The observations reported can give only a very approximate idea of numbers of Beluga passing off Coats Island or feeding in coastal waters. Ice and sea conditions and poor visibility combined to make the likelihood of seeing Belugas, especially those travelling, and hence not entering the cove, quite low on at least 30% of days during the peak period for occurrence. In addition, our watches were intermittent and amounted to no more than a few hours daily. Rates of movement observed during peak periods were > 100/h, suggesting that during periods such as 26–28 June 1995, and 17–19 June 1998, several thousand animals probably passed the camp. Assuming that the animals involved all belonged to a single summering stock, the numbers suggest that they probably were part of the western Hudson Bay

stock, as the northern Hudson Bay, eastern Hudson Bay and James Bay stocks are probably too small (< 2000; Smith and Hammill 1986; Reeves and Mitchell 1989; Richard et al. 1990) to account for numbers seen.

In view of the geographical location of the observation point, we might expect it to intercept Belugas moving towards western Hudson Bay from winter quarters in Hudson Strait. However, if their onward route was to pass through Evans and Fisher Straits we should expect a westward heading to predominate. In fact, all the passage movements seen were towards the east. If the Beluga seen from Coats Island are part of the western Hudson Bay stock, presumably they move into Evans Strait offshore, returning eastwards along the north coast of Coats Island, before heading south-west towards the mainland coast of Hudson Bay.

Many other scenarios can be suggested, including the possibility that a substantial number of Belugas winter in the Fisher Strait–Evans Strait area, at least in some years. Another possibility is that the Belugas seen from Coats Island constitute part of the northern Hudson Bay stock, about which less is known than for the other stocks (Richard et al. 1990). Tissue sampling of Belugas close to shore at Coats Island would be feasible and might allow the stock identity to be ascertained by molecular genetic techniques.

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APPENDIX 1. Numbers of Belugas seen from the Coats Island camp, 1988-1998

Date	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1 June			0						0		
2 June			0						0		
3 June			0					0	0		
4 June			0	0				0	0		
5 June			0	0				0	0		
6 June			0	0	0			0	0		
7 June			0	0	0			0	0		
8 June			0	0	0			0	0		
9 June	0		0	0	0		0	0	0		
10 June	0		0	0	0		0	0	0		
11 June	0		0	0	0		0	0	0	0	
12 June	0		0	0	0		0	0	0	0	
13 June	0		0	0	0		0	0	0	0	
14 June	0		0	0	0		0	0	0	0	
15 June	0		0	5	0		0	0	0	5	0
16 June	0		0	0	0		0	0	0	0	0
17 June	0		0	0	0		0	0	0	0	200
18 June	0		0	0	0		0	0	0	0	100
19 June	0		0	0	0		300	0	0	0	300
20 June	0		0	0	0		0	0	0	0	20
21 June	7		0	0	0		0	0	0	15	50
22 June	0		0	0	0		0	0	10	8	10
23 June	0		0	0	0		100	0	0	0	20
24 June	0		0	0	0		0	0	6	10	300
25 June	0		0	3	3		5	150	0	10	0
26 June	0		0	0	12		10	170	10	50	500
27 June	0		0	0	0		0	18	4	18	300
28 June	0		0	1	0		50	200	50	42	2
29 June	0		0	0	0		0	0	10	0	0
30 June	10		0	5	0		50	0	10	6	0
1 July	0		0	30	4		0	0	0	4	25
2 July	60		0	0	0		30	0	0	0	0
3 July	10		0	0	0		0	0	10	0	0
4 July	5		0	2	0		0	0	0	50	0
5 July	5		0	0	0		0	6	0	0	0

(continued)

APPENDIX 1. (Concluded)

Date	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
6 July	0		0	0	0		0	6	0	50	0
7 July	0		0	0	0		200	0	0	0	0
8 July	0		0	0	0		100	0	200	0	0
9 July	0		0	60	0		60	0	0	0	0
10 July	0		20	0	0		0	0	0	2	0
11 July	0		0	0	0		100	0	0	0	0
12 July	0		0	0	0		10	0	0	0	0
13 July	0		0	0	0	0	0	0	0	0	0
14 July	0		0	0	0	0	0	0	0	0	2
15 July	0		0	0	0	0	0	0	0	0	0
16 July	0		0	0	0	0	0	0	0	0	9
17 July	0		0	0	0	0	0	0	0	0	2
18 July	0		0	0	0	0	0	0	0	0	0
19 July	0		76	0	0	0	0	0	0	0	0
20 July	0		0	0	0	0	0	0	0	0	7
21 July	0		0	0	0	0	0	0	0	0	2
22 July	0		0	0	0	0	0	0	0	0	0
23 July	0		0	0	0	0	0	0	1	2	8
24 July	0		0	0	0	0	0	0	0	1	0
25 July	0		0	0	0	0	0	0	0	0	0
26 July	0		0	0	0	0	0	1	0	0	0
27 July	0	0	0	0	0	0	0	0	1	0	0
28 July	0	0	0	0	0	0	0	0	0	0	0
29 July	0	0	0	0	0	0	0	0	0	0	0
30 July	0	0	0	0	0	0	0	0	0	0	0
31 July	0	2	0	0	0	0	0	0	0	0	0
1 August	0	0	0	0	0	0	0	0	0	0	0
2 August	0	0	0	0	0	0	0	0	0	0	0
3 August	0	0	0	1	0	0	0	0	0	0	0
4 August	0	0	0	0	0	0	0	0	0	0	0
5 August	0	0	0	1	0	0	0	0	0	0	0
6 August	0	0	0	0	0	0	0	0	0	0	0
7 August	0	0	0	0	0	0	0	0	0	0	0
8 August	0	0	0	0	0	0	0	0	0	0	0
9 August	0	0	0	0	0	0	0	0	0	0	0
10 August	0	0	0	0	0	0	0	0	0	3	0
11 August	0	0	0	0	0	0	0	0	0	0	0
12 August	0	0	0	0	0	0	0	0	0	0	0
13 August	0	0	0	0	0	0	0	0	0	0	0
14 August	0	0	0	0	0	0	0	0	0	0	0
15 August	0	1	0	0	0	0	0	0	0	0	0
16 August	0	0	0	0	0	0	0	0	0	0	0
17 August	0	0	0	0	0	1	0	0	0	0	0
18 August		0	0	0	0	0	0	0	0	0	0
19 August		0	0	0	0	0	0	0	0	0	0
20 August		0	0	0	0	5	0	0	0	0	0
21 August			0	0	0	0	0	0	0	0	0
22 August			0	0	0		0	0	0	0	0
23 August			0	0	0		0	0	0	0	0
24 August			0	0	0		0	0	0	0	0
25 August				0			0	0	0	0	0
26 August				0			0	0			0
27 August				0			0	0			0
28 August				0			0	0			0
29 August				0			0	0			0

Dates in boldface are those with > 9% open water, visibility > 1 km and wind speed < 50 km/h: detectability of Beluga on other days would have been very poor.

Short-term Response of Gray Wolves, *Canis lupis*, to Wildfire in Northwestern Alaska

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There is a paucity of data concerning the effects of wildfires on large carnivores. During summer 1988 a wildfire burned 845 km² of taiga forest within the territory of two radiocollared Gray Wolf (*Canis lupus*) packs in northwest Alaska. We contrasted their use of areas that were burned with areas that were not burned before, during, and after fire. Wolves used the area that was later burned disproportionately more than expected before the fire. During and after (i.e., remainder of summer) the fire, they used the burned area more than expected during summer, but as expected during winter. Three years after the fire wolves began using the burned area similarly to their use before the fire; up until that time, wolves used the burned area less than it had been used prior to the burn. We attributed the changes in wolf distribution to changes in ungulate availability which were probably caused by the wildfire.

Key Words: Gray Wolf, *Canis lupus*, caribou, *Rangifer tarandus*, habitat selection, satellite telemetry, taiga forest, burn, territory sizes, Alaska.

Forest fires are important in the dynamics of boreal forests, but forest fires remain a contentious issue, particularly in the eyes of a public which views fire as deleterious to wildlife (Latour et al. 1994). Although the effects of wildfire on ungulates have been studied extensively [see Peek (1986) and Riggs et al. (1996) for reviews] there is a paucity of data concerning the effects of fire on carnivore species. Peek (1986) indicated that the response of predators to fire involved the fire's effect on prey and prey habitat. Patton and Gordon (1995) suggested that density of mid-sized carnivores would initially increase following a fire due to increased prey vulnerability. Ogen-Odoi and Dilworth (1984) found that hare (*Lepus* spp.) populations increased within three months following a prescribed burn in a 30 ha savanna grassland, but that large (> 25 kg) predators were not affected. Rabinowitz (1990) suggested that man-caused annual fires in central Thailand helped maintain dry deciduous dipterocarp forest but that Leopard Cats (*Felis bengalensis*) avoided these areas and preferred unburned areas. Blanchard and Knight (1990) reported that some adult Grizzly Bears (*Ursus arctos*) may have succumbed to the fire in Yellowstone National Park, but that the most important short-term impact was increased availability of ungulate carcasses during autumn. Other than these studies, we found no literature describing the response of large carnivores to wildfire.

Ballard et al. (1997) studied the ecology of Gray Wolves (*Canis lupus*) in relation to migratory Caribou (*Rangifer tarandus granti*) in northwestern Alaska during 1987 through 1992. During summer 1988 a wildfire burned approximately 845 km² of a 12 280 km² study area. The wildfire occurred primarily within the boundaries of two wolf packs that were studied from April 1987 through April 1992. Our objectives were to compare wolf response and use of the burned area before and after the wildfire, and discuss the short-term impacts of this fire on wolves.

Study Area

Topography ranged from flat plains along the major river systems (Kobuk and Selawik Rivers) to rolling hills in the Waring Mountains. Elevation ranged from near sea level along the Selawik River to about 640 m in the Waring Mountains. Vegetation varied from unvegetated sand dunes (e.g., Greater and Little Kobuk Sand Dunes), gravel bars, rock scree, and lakes to wetlands and marshes or dense White Spruce (*Picea glauca*) forests along the Selawik River. Willows (*Salix* spp.) occurred throughout, but were most common along riparian areas and least common in open tundra. Sparse to dense stands of taiga scrub forest composed of White and Black spruce (*P. mariana*) or alpine and arctic tundra composed most of the territory.

The area has a maritime climate during snow-free periods and long cold periods during winter months. Temperature extremes ranged from -23°C in winter to 32°C in summer. Annual precipitation ranged from 380 to 500 mm in lowland areas to 760 mm in mountainous areas.

Primary ungulate wolf prey within the Rabbit Mountain and Dunes Pack territories included Caribou and Moose (*Alces alces gigas*). Important secondary prey items included Beaver (*Castor canadensis*), Snowshoe Hare (*Lepus americanus*), two species of squirrels (*Tamiasciurus hudsonicus* and *Spermophilus parryi*), microtine (Microtinae) rodents, and numerous bird species (Ballard et al. 1997).

A wildfire burned approximately 845 km² of taiga forest during June and July 1988, which occurred within the territories of two wolf packs: Rabbit Mountain Pack (RMP) and the Dunes Pack (DP). The territories of the RMP and DP included portions of Kobuk Valley National Park and Selawik National Wildlife Refuge in northwest Alaska. According to satellite telemetry, RMP occupied annually an area ranging in size from 1617 to 4078 km², while DP occupied an area of 1508 to 5124 km² (Ballard et al. 1999). The wildfire started as a single source lightning strike about 15 June 1988 (Saperstein 1993). The fire began in the northern portion of the study area and was periodically fought during summer. The fire progressed south until it was extinguished by rainfall in mid-August 1988. Although the burn was relatively homogeneous over the 845 km², a fire mosaic was formed and some wet areas were not burned. The southern and northwestern boundaries of the fire formed a series of fingers and wet areas surrounding lakes and streams were not burned (Jerry et al. 1989*); however, the fire burned continuously over 85 000 hectares and many spruce were killed. The severity of the fire varied significantly over the area and some areas reburned creating an irregular mosaic pattern of fire intensity and reburning. The fire burned down to mineral soil on some of the high north-south ridge lines and on some of the spruce areas, particularly where reburning occurred (M. J. Foote, U.S. Forest Service (retired), personal communication). The impact of fire on Caribou habitat remains a controversial issue, but is thought to be beneficial to Moose habitat (Jerry et al. 1989*). History of both RMP and DP were provided by Ballard et al. (1997). Detailed descriptions of the study area were provided by Ballard (1993) and Ballard et al. (1997).

Methods

During 1987 through 1991 we captured 11 wolves in two packs by darting from a helicopter for radio-

collaring using methods described by Ballard et al. (1982, 1991); four wolves within the RMP were equipped with VHF transmitters and three were equipped with satellite transmitters (herein referred to as platform transmitter terminals [PTTs]), while within DP, which later replaced the Rabbit Mountain pack, two were equipped with VHF transmitters and two were equipped with PTTs (all manufactured by Telonics, Inc., Mesa, Arizona). Accuracy, precision, and performance of PTTs were described by Ballard et al. (1995). Average error of PTT locations was 577 ± 610 m (Ballard et al. 1995). The PTTs provided 1 to 3 locations/6 hour transmission daily for the first 30 days and then 1 to 3 locations every other day until battery exhaustion (Ballard et al. 1995). Rabbit Mountain PTTs functioned as follows: year 1 = 17 April 1987 through 27 April 1988; year 2 = 24 April 1988 through 16 February 1989; and year 3 = 7 April 1989 through 18 May 1990. Dunes pack PTTs functioned as follows: year 1 = 7 April 1989 through 1 February 1990; and year 2 = 17 March 1990 through 13 May 1991.

We defined seasons based upon a biological year; winter from 1 October through 30 April and summer 1 May through 30 September (Ballard et al. 1997). We defined territory size using minimum convex polygons (Mohr 1947). The minimum convex polygon method basically connects outer locations and calculates the area contained within. For these analyses we used only locations provided by PTTs because satellite telemetry provided more continuous contact, contact during periods when VHF transmitters could not be located, and greater numbers of locations than those provided by VHF telemetry (Ballard et al. 1999).

We converted PTT locations to Universal Transverse Mercator coordinates that were entered into ARC/INFO© (Environmental Systems Research Inst., Inc., Redlands, California) geographic information system (GIS) for plotting seasonal and annual territories. We also used GIS to determine the proportion of the burned area within seasonal and annual territories. We used the proportion of burned versus unburned area to estimate the expected number of wolf locations within each area. Expected numbers of wolf locations were compared with observed numbers of locations within a biological year by 2×2 contingency analyses. Differences in proportions observed in and out of the burn among years for individual packs were also compared by 2×2 contingency analyses (Conover 1980). Differences were considered significant when $P < 0.10$.

Results

For one year (1987–1988) prior to the wildfire, the area that was later burned was used by RMP proportionately more than expected during summer ($\chi^2 = 46.5$, $P < 0.001$), winter ($\chi^2 = 18.8$, $P < 0.001$), and

*See Documents Cited section

TABLE 1. Number of radiocollared wolf pack locations observed versus expected within a burned area before (1987–1988) and after the fire (1988–1992) in Northwest Alaska.

			Number of locations (%)					
Pack Name	Burn Period	Season	In Burn		Out of Burn		Statistical Test	
			Observed	Expected	Observed	Expected	χ^2	P - Value
Rabbit Mountain	Pre-burn 1987–1988	Summer	125 (76.6)	64 (39.0)	39 (23.8)	100 (61.0)	46.5	<0.001
		Winter	81 (45.0)	42 (23.3)	99 (55.0)	138 (76.7)	18.8	<0.001
		Annual	206 (59.9)	76 (22.1)	138 (40.1)	268 (77.9)	101.6	<0.001
Rabbit Mountain	Post-burn 1988–1989	Summer	36 (62.1)	18 (31.0)	22 (37.9)	40 (69.0)	11.2	<0.001
		Winter	5 (25.0)	5 (25.0)	15 (75.0)	15 (75.0)	0.0	1.0
		Annual	41 (52.6)	19 (24.4)	37 (47.4)	59 (75.6)	13.1	<0.001
Rabbit Mountain	Post-burn 1989–1990	Summer ¹	56 (76.7)	42 (57.5)	17 (23.3)	31 (42.5)	6.1	0.01
		Winter	28 (30.8)	20 (22.0)	63 (69.2)	71 (78.0)	1.8	0.18
		Annual	84 (51.2)	34 (20.7)	80 (48.8)	130 (79.3)	33.1	0.001
Dunes	Post-burn 1990–91	Summer	26 (17.7)	44 (29.9)	121 (82.3)	103 (70.1)	6.1	0.01
		Winter	89 (48.4)	99 (53.8)	95 (51.6)	85 (46.2)	1.1	0.30
		Annual	115 (34.7)	175 (52.9)	216 (65.3)	156 (47.1)	22.1	<0.001
Dunes	Post-burn	Summer	51 (48.1)	49 (46.2)	55 (51.9)	57 (53.8)	0.08	0.78
		Winter	49 (45.8)	19 (17.8)	58 (54.2)	88 (82.2)	19.4	0.001
		Annual	100 (46.9)	35 (16.4)	113 (53.1)	178 (83.6)	45.8	<0.001

¹Wildfire occurred during June 15 through about mid-August 1988.

annually ($\chi^2 = 101.6$, $P < 0.001$) (Table 1, Figure 1). In 1988–1989, RMP used the burned area disproportionately more during summer while the fire was in progress ($\chi^2 = 11.2$, $P < 0.001$) and annually ($\chi^2 = 13.1$, $P < 0.001$) (Figure 1), but used the burned area as expected during winter ($\chi^2 = 0.0$, $P = 1.0$). However, between 1987–1988 (pre-burn) and 1988–89 (during and post-burn) the pack used the area proportionately less in 1988–1989 during summer ($\chi^2 = 4.3$, $P = 0.04$), winter ($\chi^2 = 2.9$, $P = 0.09$), and annually ($\chi^2 = 4.6$, $P = 0.03$) than during 1987–1988.

During 1989–1990, after the fire in 1988–1989, RMP used the burned area more than expected during summer ($\chi^2 = 6.1$, $P = 0.01$) and annually ($\chi^2 = 33.1$, $P < 0.001$) (Table 1, Figure 1), but in proportion to availability during winter ($\chi^2 = 1.8$, $P = 0.18$). The burned area was also used proportionately less in 1989–1990 than during 1987–1988 prior to the fire during summer ($\chi^2 = 19.8$, $P < 0.001$), winter ($\chi^2 = 5.1$, $P = 0.02$), and annually ($\chi^2 = 9.7$, $P = 0.002$).

During late 1989–1990 all members of RMP were killed by hunters or rabies (Ballard et al. 1997) and the DP occupied the area previously held by RMP until 1990. The DP used the burn area during 1990–1991 proportionately less than expected during summer ($\chi^2 = 6.1$, $P = 0.01$) and annually ($\chi^2 = 22.1$, $P < 0.001$), but in proportion to availability during winter ($\chi^2 = 1.1$, $P = 0.30$) (Table 1, Figure 2).

During 1991–1992 DP used the burned area more during winter ($\chi^2 = 19.4$, $P < 0.001$) and annually ($\chi^2 = 45.8$, $P < 0.001$), but in proportion to availability during summer ($\chi^2 = 0.08$, $P = 0.78$) (Figure 2). During 1991–1992 DP used the burn more during summer ($\chi^2 = 26.9$, $P < 0.001$) and annually (χ^2

$= 8.1$, $P = 0.005$), but during winter in the same proportion ($\chi^2 = 0.18$, $P = 0.67$) as during 1990–1991.

Discussion

Blanchard and Knight (1990) indicated that the most important immediate effect of the 1988 Yellowstone fire on Grizzly Bears was the increased availability of ungulate carcasses during autumn. Otherwise, the fire had no effect on choice of den sites, annual range sizes, or movement rates. Our results suggest that the burned area was selected (i.e., used proportionately more than by chance alone) by wolves during summer and winter prior to the fire. During the fire in 1988–1989, RMP used the burn area disproportionately more than expected, but during winter in proportion to expected values, less in both cases than during 1987–1988.

We observed high wolf use of the burned area while the fire was in progress during 1988. We doubt that the increased use was due to an increase in ungulate carcasses as suggested by Blanchard and Knight (1990) in Yellowstone National Park because of the relatively slow rate of spread of the burn in our study area. Also, Gasaway and DuBois (1985) found no increase in Moose mortality following a wildfire in interior Alaska nor did Gasaway et al. (1989) detect any large-scale shifts in Moose movements following wildfire.

Prior to the fire, the burned area was used inconsistently by Caribou as a wintering area for 3 of 5 winters; Caribou use of the area during winter and early spring declined after 1988 through at least 1990 (Spindler 1990*; Ballard et al. 1997) and apparently longer (Saperstein 1993). Wolf use of the area also declined from 1987–1988 levels during winters

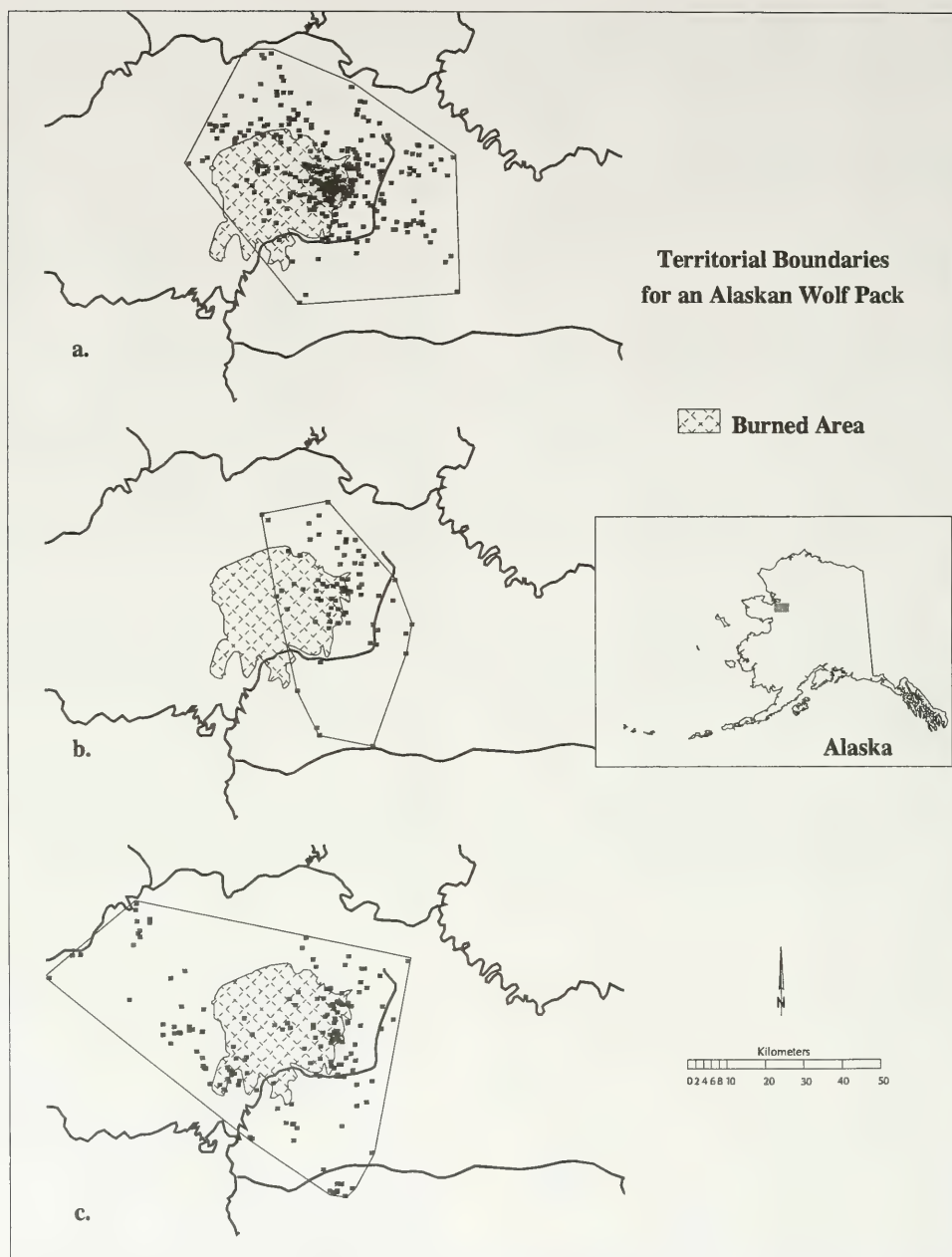


FIGURE 1. Distribution of annual Rabbit Mountain wolf pack locations during 1987–1988 (a), 1988–1989 (b) and 1989–1990 (c) in relation to territory boundary and boundaries of a 845 km² wildfire that burned in northwest Alaska during summer 1988.

1988–1989 and 1989–1990. Saperstein (1993) indicated that the wildfire reduced the relative frequency and biomass of most vascular plants on this area. However, she indicated that in 1990, following the fire, protein content, digestibility, and availability of *Eriophorum vaginatum* increased following the fire,

and that the fire made the site an attractive feeding area for Caribou during late winter. However, the increased quality and quantity of *E. vaginatum* was short-lived, and she predicted that lowered availability of lichens and the increased frequency of bryophytes would persist for longer periods.

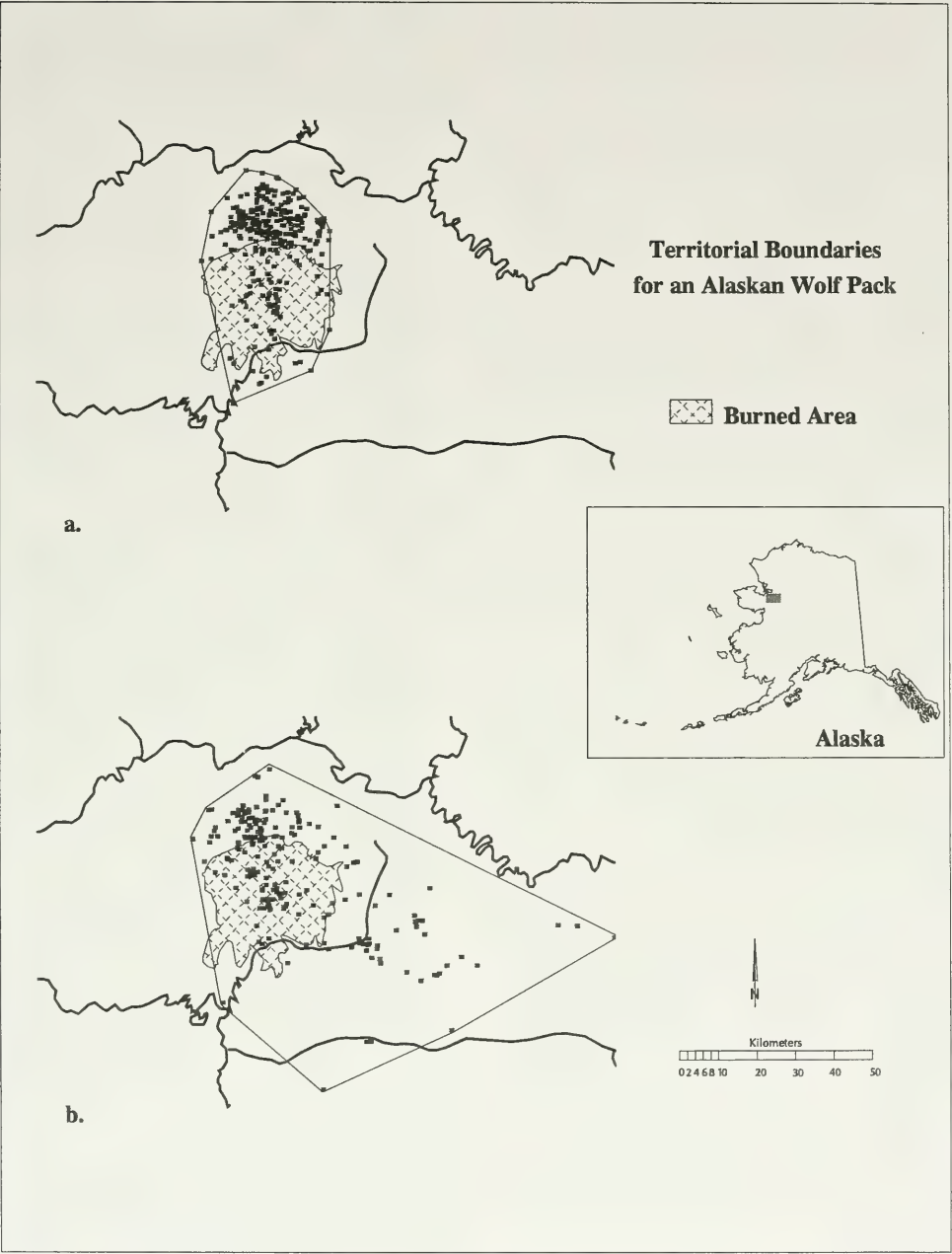


FIGURE 2. Distribution of annual Dunes wolf pack locations during 1990–1991 (a) and 1991–1992 (b) in relation to territory boundary and boundaries of a 845 km² wildfire that burned during summer 1988 in northwest Alaska.

The RMP continued to use the burned area disproportionately to availability during summer 1989 following the fire. Although Caribou stopped using the burn as a wintering area after 1988, they continued to use the edge of the burn during migration during

late winter and spring (Spindler 1990*; Ballard et al. 1997). Caribou were observed feeding in unburned islands and on green emergent vegetation in wetland areas during late spring 1989 (Spindler 1990*). Analyses of summer wolf scats indicated that

Caribou and Moose were the predominant food items for both study packs (Spaulding et al. 1998) suggesting that these prey species were still present in sufficient numbers to constitute important prey items.

No radiocollared wolves died as a result of the wildfire. Each pack produced pups that survived each year (Ballard et al. 1997) and RMP denned on the southeastern boundary of the wildfire while it was in progress with no apparent adverse effects (W. B. Ballard, unpublished data).

The wildfire in northwestern Alaska during summer 1988 had no apparent short-term effects on the population dynamics of wolves in the area. Wolves used the burned areas more than expected during the fire in 1988 and during summer 1989. However, during subsequent winters, apparently as a result of shifts in Caribou distribution, possibly caused by the wildfire, wolves used the burned area less than before the wildfire for at least two years. No data were available on changes in Moose distribution before or after the fire. Wolf usage of the burned area appeared to return to near pre-fire conditions after three years. Wildfires of the size and intensity which occurred in this study do not appear to have adverse short-term effects on the population dynamics of wolves apparently because shifts in Caribou distribution were not greater than normal annual variation and small unburned areas appeared to attract Caribou during spring (Spindler 1990*). However, larger wildfires and fires of greater intensity may impact wolf populations if they result in large changes in prey distributions.

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Status of the Rayed Bean, *Villosa fabalis* (Bivalvia: Unionidae), in Ontario and Canada†

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The Rayed Bean, *Villosa fabalis*, is a very small freshwater mussel that lives in stable substrates of sand or gravel in shallow riffle areas of rivers and streams. Its host fish in Canada is unknown. Although population trends are difficult to quantify due to a lack of numerical data, the species is generally recognized to have significantly declined throughout its range in recent years. Its global rank was uplisted from G2 to G1G2 by The Nature Conservancy in 1997, and it is currently ranked S1 in most jurisdictions. In Canada, *Villosa fabalis* was historically known from the Thames, Sydenham and Detroit Rivers and western Lake Erie in southwestern Ontario. It is now restricted to the middle reach of the Sydenham River. Siltation and agricultural chemicals are likely the most significant threats to the continued existence of this species in Canada. Pollution from urban sources and livestock farming may have caused the extirpation of the species from the Thames River. As the Sydenham River population is one of only a few remaining populations in North America that still show signs of recruitment, preserving this population may be important for the global survival of the species.

Key Words: Rayed Bean, *Villosa fabalis*, Unionidae, freshwater mussels, endangered species, COSEWIC, Great Lakes.

The Rayed Bean, *Villosa fabalis*, is a small unionid belonging to the Subfamily Lampsilinae. It was originally described by Lea in 1831 as *Unio fabalis* (Simpson 1914), with the type locality being the Ohio River (LaRoque 1953; Simpson 1914). The authority for the current nomenclature is Turgeon et al. (1988). *Villosa fabalis* can be distinguished from other Canadian species of freshwater mussels by its very small size, elliptical shape, crowded wavy green rays, and hinge teeth that are unusually heavy for the size of the animal (Clarke 1981; Cummings and Mayer 1992). Clarke (1981) describes the shell as sub-elliptical, very small, and solid, with a mid-anterior shell wall thickness of 2.5 mm. Females tend to be more inflated and more broadly rounded posteriorly than males. The periostracum is normally light or dark green and covered with wide or narrow, wavy, darker green rays that are clearly apparent except on old, blackened specimens. The nacre is silvery white and iridescent. The beaks are narrow, slightly elevated above the hinge line and not excavated, and the beak sculpture is fine and composed of about five crowded double-looped ridges. The hinge teeth are relatively heavy with erect, pyramidal, serrated pseudocardinals, short laterals with diagonal serrations, and a thick interdentum.

According to Cummings and Mayer (1992) and TNC (1987*), shells are normally 25–35 mm in length. However, specimens up to 38 mm long have been reported in Canada (Clarke 1981; Metcalfe-Smith et al. 1999). The Rayed Bean may be confused with the Rainbow Shell, *Villosa iris*, but the latter species grows about three times as large and has a thinner shell with more delicate hinge teeth and fewer rays. Young specimens of the Kidneyshell, *Ptychobranchus fasciolaris*, or the Spike, *Elliptio dilatata*, may also be mistaken for *V. fabalis*, although their beak sculptures differ. Figure 1 shows the right valves of a fresh male shell (left) and female shell (right) taken from the Sydenham River in southwestern Ontario.

Distribution

The Rayed Bean was historically known from Alabama, Illinois, Indiana, Kentucky, Michigan, New York, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia (TNC 1997*) and Ontario; see inset, Figure 2A. The historical distribution of the species is summarized here using information from Burch (1975), Clarke (1981), Bogan and Parmalee (1983) and Strayer and Jirka (1997). *Villosa fabalis* was once widely but discontinuously distributed throughout the Ohio and Tennessee River systems, including the Wabash, Monongahela, Elk, Allegheny, Green, Rouge, Clinch, Powell, North Fork Holston, and Duck Rivers. It also occurred in western Lake Erie and its tributaries, including the Maumee River, and in tributaries to the St. Clair River and Lake St. Clair

†Endangered status assigned by COSEWIC 19 April 1999.

*See Documents Cited section.

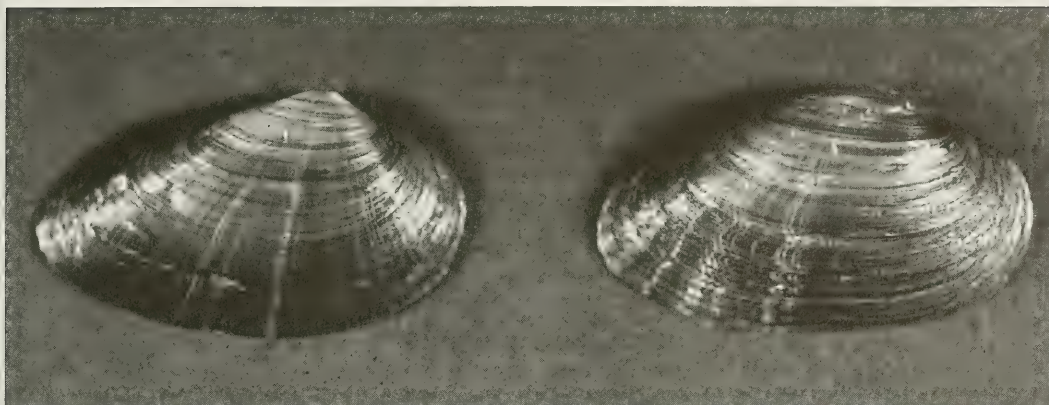


FIGURE 1. External shell morphology of a male (left) and female (right) specimen of *V. fabalis* collected as spent shells from the Sydenham River near Shetland, Ontario in August 1998. Right valves are shown for both sexes.

such as the Pine River (Hoeh and Trdan 1985) and the Clinton River (Strayer 1980). A previously unknown population was recently discovered in the Belle River, Michigan (J. B. Layzer, U.S. Geological Survey, Tennessee Cooperative Fishery Research Unit, Tennessee Tech University, Cookeville, Tennessee, personal communication, April 1999). The easternmost records for this species are those from western New York (Strayer et al. 1991). In Canada, *V. fabalis* was known from the Detroit River, the Sydenham and Thames Rivers in the Lake St. Clair drainage, and western Lake Erie (LaRoque 1953; Clarke 1981; museum records described below).

Figure 2A illustrates the historical distribution of *V. fabalis* in Ontario (and Canada) based on occurrence records from the National Water Research Institute's Lower Great Lakes Unionid Database. The database and its data sources are described in detail in Metcalfe-Smith et al. (1998a). At present, the database consists of over 5000 records for 40 species of mussels collected from the Canadian waters of the lower Great Lakes drainage basin between 1860 and 1998. A total of 20 historical records for *V. fabalis* were available from the holdings of the Ohio State University Museum of Biological Diversity (OSUM), the Royal Ontario Museum (ROM) and the University of Michigan Museum of Zoology (UMMZ); the personal records of Carol B. Stein (retired from the OSUM) and Michael J. Oldham (Natural Heritage Information Centre, Ontario Ministry of Natural Resources); the private collections of Herbert D. Athearn (Emeritus, Tennessee Academy of Science); and Clarke (1992).

Protection

Canada does not have federal endangered species legislation at this time. However, Ontario is one of five provinces that have stand-alone Endangered

Species Acts (Aniskowicz 1997; and B. T. Fowler [nee Aniskowicz], personal communication, September 1999). Species classified as provincially Endangered, and their habitats, are protected from willful destruction under these provincial acts, but in Ontario there is currently no protection for Threatened or Vulnerable species. The Provincial Policy Statement under Section 3 of Ontario's Planning Act prohibits development and site alteration in the habitats of Threatened and Endangered species. The Rayed Bean is currently being considered for Endangered status in Ontario by the Committee On the Status of Species At Risk in Ontario (COSSARO) and, if approved, would receive provincial protection. Other mechanisms for protecting mussel habitat in Ontario include the Ontario Lakes and Rivers Improvement Act, which prohibits the impoundment or diversion of a watercourse if it would cause siltation; and the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food and Rural Affairs, which is designed to reduce the erosion of agricultural lands. Stream-side development in Ontario is managed through flood plain regulations enforced by local conservation authorities. Most land along the reach of the Sydenham River where *V. fabalis* presently occurs is privately owned and in agricultural use. Two small properties, the 7-ha Shetland Conservation Area and the 20-ha Mosa Township forest, are publicly owned (Muriel Andreae, St. Clair Region Conservation Authority, personal communication, March 1998).

The federal Fisheries Act may represent the most important legislation protecting the habitat of the Rayed Bean in Canada. Under this Act, freshwater mussels are considered to be shellfish, which are included in the definition of "fish" and therefore afforded protection in theory. In practice, the Fisheries Act is mainly applied to habitats that sup-

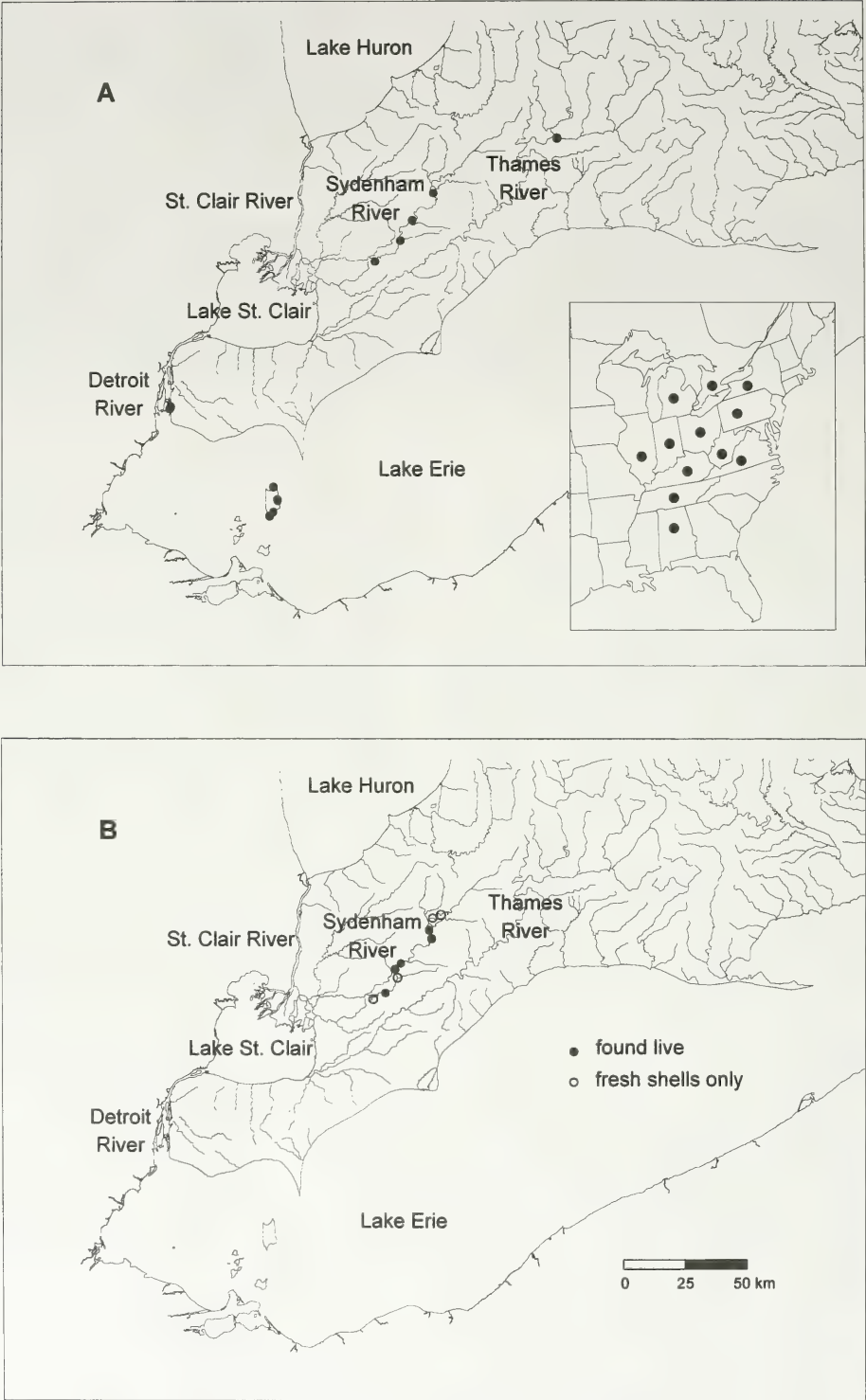


FIGURE 2. Distribution of *Villosa fabalis* in Ontario. A. Historical distribution (inset shows historical North American distribution). B. Presumed current distribution, based on the results of 1997–1998 surveys.

port recreational or commercial fisheries. As *V. fabalis* presently occurs in a river that supports a recreational fishery, its habitat should be indirectly protected by the Fisheries Act.

Villosa fabalis was previously listed as a Category 2 Federal Candidate under the U.S. Endangered Species Act (Cummings and Mayer 1992); however, maintenance of this list was discontinued in 1996 (Roth 1997*). Category 2 species were defined as those species for which there was some evidence for vulnerability, but not enough data for them to be listed as Endangered or Threatened (Cummings and Mayer 1992). Because state and local governments are no longer asked to take Category 2 candidates into account in their environmental planning, this change in listing procedures will significantly weaken the protection of species such as *V. fabalis* in the United States (Roth 1997*). The Rayed Bean is afforded state protection in Alabama, Indiana, Kentucky, Michigan and Ohio, where it is currently listed as endangered or of special concern (TNC 1997*; TVA 1996*). In Michigan, for example, the Natural Resources and Environmental Protection Act provides for the possible acquisition of land or aquatic habitat, and the establishment of programs necessary for the conservation, protection, restoration and propagation of listed species (Michigan DNR 1998*). *Villosa fabalis* has also been proposed for endangered status in New York (D. L. Strayer, Institute of Ecosystem Studies, Millbrook, New York, personal communication, June 1998).

Population Sizes and Trends

The Rayed Bean is considered to be a rare species (Clarke 1981; Strayer and Jirka 1997), but it has been suggested that its rarity may be more apparent than real because it is a small species that burrows deeply into the substrate and could be easily overlooked (TNC 1987*). Abundant populations have been seen on occasion. For example, Hoggarth et al. (1998*) recently found it to be the third most common species of unionid in a stretch of the upper Blanchard River in northwestern Ohio. It also ranked third in abundance (21% of 3452 mussels) among 17 species relocated from the impact zone of a bridge replacement project on the upper Allegheny River in Pennsylvania in 1998, and second in abundance (9% of 15 737 mussels) among 19 species moved from a site on French Creek, Pennsylvania for the same reason (G. F. Zimmerman, EnviroScience, Inc., Cuyahoga Falls, Ohio, personal communication, April 1999). Densities of *V. fabalis* at these two sites were 0.261 and 0.73 individuals/m², respectively, whereas densities as high as 5.5 individuals/m² have been seen elsewhere in these systems.

It is difficult to quantify population trends for *V. fabalis*, as many studies note only its presence or absence (e.g., Clarke 1973), or indicate that it was

"rare". However, several studies provide evidence that the species is now very rare and/or in decline. For example, Strayer (1980) found *V. fabalis* to be represented by spent shells at just four of 76 sites surveyed on the Clinton River, Michigan, in 1977–1978, whereas it had been found (presumably alive) at four of 26 sites prior to 1935. The species was also represented by spent shells only at just two of 24 sites on the Raisin River in southeast Michigan in 1976–1977 (Strayer 1979), and it was one of nine species found to be rare (defined as <1 mussel found per person-hour of collecting) in three small tributaries to the St. Clair River, Michigan, in 1982–1983 (Hoeh and Trdan 1985). In New York, *V. fabalis* is described as "rare in the State and gone from some historic sites" (Schneider 1998*). According to Strayer and Jirka (1997), small populations of *V. fabalis* still persist at two of several sites where it previously occurred in the Allegheny River basin in New York. It was represented by one live specimen at one site and spent shells at two other sites in a short stretch of Olean Creek during a survey of 26 sites in the Allegheny River system between 1987 and 1990 (Strayer et al. 1991). In a subsequent survey of 10 sites in the Allegheny basin, Strayer (1995*) observed four live specimens at one site on Cassadaga Creek. A total of 226 mussels of 13 species were found at this site; thus, *V. fabalis* constituted less than 2% of the community. In the Tennessee River system, the current range of this species is restricted to a few locations in the Duck and Clinch rivers (TNC 1987*). As noted by Bogan and Parmalee (1983), the majority of previously known populations in the state of Tennessee are now inundated by reservoirs. In the United States, *V. fabalis* is now found most frequently (1970 to present) in the Ohio drainage, including French Creek (tributary of the Allegheny River), Elk River (tributary of the Kanawha River), Eagle Creek (tributary of the Kentucky River), Muskingum River, Little Miami River and three tributaries (Big Darby Creek, Deer Creek and Olentangy River) of the Scioto River (TNC 1987*).

The earliest records for *V. fabalis* in Canada date back to the 1930s. It was reported from the Detroit River at Bois Blanc Isle by Bryant Walker in 1934 (UMMZ Catalogue # 92807), and it was collected by C. Goodrich at nearby Amherstberg in 1935 (UMMZ Catalogue # 92823). Bryant Walker also collected the species from a site near Pelee Island in western Lake Erie in 1934 (UMMZ Catalogue # 928822). It was found several more times near Pelee Island between 1958 and 1967 (fresh shells only), but a survey of 17 sites throughout the western basin of Lake Erie in 1991 (Schloesser and Nalepa 1994) failed to reveal any trace of *V. fabalis*. It was not found during surveys of 29 sites in Lake St. Clair in 1986, 1990, 1992 or 1994 (Nalepa et al. 1996); however,

there are no historical records for the species from Lake St. Clair, so it may never have occurred there.

Sydenham River

The Rayed Bean was first collected alive from the Sydenham River in 1963 by H. D. Athearn near the town of Shetland (Clarke 1973). It was subsequently found alive in 1965 and 1967 near Florence and Alvinston, respectively (C. B. Stein, personal communication, September 1997). Athearn reported it from another site near Shetland in 1967, but did not say if it was found alive. Stein surveyed two sites in 1973, namely, her 1965 site and a new site at Dawn Mills, and found only one fresh valve at each location. The first extensive survey of the Sydenham River was conducted in 1971 by Clarke (1973), who visited 11 sites. Although he did not find *V. fabalis*, it should be noted that he used a smaller sampling effort than previous collectors (Clarke averaged 1h per site, whereas Athearn conducted a 4h survey and Stein searched for 3–6h). Mackie and Topping (1988) surveyed 20 sites on the Sydenham River in 1985 using a sampling effort of 1h per site, and found no trace of *V. fabalis*. Clarke (1992) revisited the river in 1991, and surveyed 16 sites. He spent between 0.4 and 8.0 person-hours (p-h) at each site and found many more live species than Mackie and Topping (1988), including a single specimen of *V. fabalis* at a site near Alvinston. A few weathered valves were also collected from this site by Oldham (personal records) in 1991 and 1992.

In 1997 and 1998, Metcalfe-Smith et al. (1998b, 1999) surveyed 66 sites on the Grand, Thames, Sydenham, Ausable and Maitland Rivers in the Lake Erie, Lake St. Clair and lower Lake Huron drainages to assess the current conservation status of rare species of freshwater mussels in southwestern Ontario. They used the timed-search sampling

method, which is particularly effective for detecting rare species (Strayer et al. 1997), and an intensive sampling effort of 4.5 p-h/site. Sites that were known to support these species in the past were targeted, including five sites on the Sydenham River where live specimens or shells of *V. fabalis* had been found between 1963 and 1991. The data for all survey sites that produced live animals and/or shells in 1997–1998 are presented in Table 1. Based on the presence of live specimens, the current range of *V. fabalis* in the Sydenham River extends over a distance of approximately 45 km between Alvinston and Croton (see Figure 2B). A total of 15 live animals numbering 1–6 individuals/site were encountered at five of seven sites within this reach, and a few fresh shells were found at a sixth site. Several fresh shells were also taken from two sites above and one site below the reach. If fresh shells are taken to indicate the presence of live animals at perhaps lower densities, the range of *V. fabalis* expands to 65 km. As only one of the 12 sites surveyed for mussels on the main branch of the Sydenham River was outside of this reach, it is possible that the species may occur further upstream. However, there is no mussel habitat below Dawn Mills, where water levels fluctuate with the levels in Lake St. Clair.

A comparison of Figures 2A and 2B suggests that the current range of *V. fabalis* in the Sydenham River has changed little over time; however, there is some evidence to indicate that abundance may have declined. Four of the sites surveyed by Metcalfe-Smith et al. (1998b, 1999) in 1997–1998 had been sampled 24 to 34 years earlier by Athearn or Stein, using similar sampling efforts. Comparisons of the historical and current data show a decline over time in the numbers of live specimens and/or fresh shells found at most sites (Table 2).

TABLE 1. Numbers of live specimens and spent shells of *V. fabalis* found in the Sydenham River (SR) and Thames River (TR) in 1997–1998*. Sites ordered in an upstream to downstream direction for each river.

Site number	Nearest urban centre	Live specimens	Fresh shells		Weathered shells	
			Whole	Valves	Whole	Valves
SR-11	Alvinston	0	1	0	0	0
SR-1	Alvinston	0	0	0	0	7
SR-10	Alvinston	0	2	0	0	0
SR-2	Alvinston	1	0	1	0	1
SR-3	Alvinston	1	0	2	3	0
SR-7	Shetland	5	0	20	0	0
SR-17	Florence	6	4	0	0	0
SR-5	Florence	0	1	2	0	0
SR-6	Croton	2	6	11	0	0
SR-12	Dawn Mills	0	0	1	0	0
TR-2	Dorchester	0	0	0	0	4
TR-3	London	0	0	0	0	26
TR-5	Oneida Reserve	0	0	0	0	10
TR-8	Kent Bridge	0	0	0	0	1

*data taken from Metcalfe-Smith et al. (1998b, 1999); a total of 17 sites were surveyed on the Sydenham River and 16 sites on the Thames River.

TABLE 2. Comparison of historical (1963-1973) and current (1997-1998) data on numbers of live specimens and fresh spent shells of *V. fabalis* collected from four sites on the Sydenham River.

Site number	Collector, date	Historical data			Current data*		
		Live	Whole shells	Valves	Live	Whole shells	Valves
SR-2	Stein 1967	2	16	3	1	0	1
SR-4	Athearn 1963	1	0	0	0	0	0
SR-5	Stein 1965	1	9	2	0	1	2
	Stein 1973	0	0	1	"	"	"
SR-12	Stein 1973	0	0	1	0	0	1

*data taken from Metcalfe-Smith et al. (1998b, 1999).

Live specimens of *V. fabalis* collected from the Sydenham River in 1997-1998 measured 20 to 38 mm in length, while spent shells ranged from 15-36 mm. As 90% of the shells were fresh, i.e., probably left by animals that died within the past year, data for live specimens and shells were combined to generate an overall size class distribution (Figure 3) for the species in this river. The broad range of sizes and fairly even distribution of individuals for both live specimens and shells is indicative of a healthy, reproducing population. The sex ratio could not be determined for live animals, as the specimens found in 1997 were not sexed. However, the sex ratio for the 64 shells was somewhat skewed towards females (62% females: 38% males), with female shells being smaller (23 mm) on average than male shells (28 mm). There is no information in the literature on normal sex ratios for this species.

Thames River

Only one historical record exists for *V. fabalis* from the Thames River. A single fresh whole shell was collected by J. C. Medcof in 1934 (ROM Catalogue # M3470) from the south branch of the Thames River at a location described only as being in the "east part of London". Metcalfe-Smith et al. (1998b, 1999) surveyed 16 sites throughout the Thames River watershed in 1997-1998, including one site in the vicinity of Medcof's site. No live specimens or fresh shells were found at any site; however, a total of 41 weathered valves were found at four sites, including 26 from the site located near Medcof's historical site (see Table 1). These data prove that *V. fabalis* once occurred in the Thames River; however, it has apparently now been lost.

Habitat

Villosa fabalis tends to inhabit the headwaters and smaller tributaries of river systems, where it is found in or near riffle areas (TNC 1987*). Cummings and Mayer (1992) describe its habitat as "Lakes and small to large streams in sand or gravel". It is occasionally reported from shallow water areas of lakes (TNC 1996*) and large rivers. For example, historical records show that it has been found along the edges of islands in Lake Erie and the Detroit River.

In southeastern Michigan, Strayer (1983) found it to be scattered in the lower courses of rivers and medium-sized streams on the outwash plains. Such streams are characterized by low gradients, clear water, steady flows, and substrates of sand and gravel. All shells and live animals found by Strayer et al. (1991) in the New York waters of the Allegheny drainage were on "...shallow gravelly riffles among *Myriophyllum*, apparently the typical habitat for this species...". The Rayed Bean is usually found deeply buried in the substrate, among the roots of aquatic vegetation. As a result, this species may not be as sensitive to flow rate fluctuations in its habitat as some other mussel species (TNC 1987*). Live specimens encountered in the Sydenham River during recent surveys (Metcalfe-Smith et al. 1998b, 1999) were found buried in stable substrates of sand or fine gravel, generally in low flow areas along the margins of the river or the edges of small islands.

General Biology

Although specific information regarding the biology and ecology of *V. fabalis* is limited, general unionid biology is applicable (USFWS 1994). During spawning, males release sperm into the water and females living downstream take in the sperm through their incurrent siphons. Female mussels brood their young from the egg to the larval stage in their gills, using the posterior portions of their outer gills as marsupia. Once expelled into the water by the female, the larval mussels, or glochidia, must attach to the gills or fins of an appropriate fish host in order to complete their metamorphosis. *Villosa fabalis* is reported to be a long term brooder (bradyctictic) that holds its glochidia over winter for spring release (Ortmann 1909, as cited in TNC 1987*). The glochidia have been described as subspatulate in shape (Bogan and Parmalee 1983), or as rounded but with a straight hinge line (Clarke 1981). They are 200 µm high and 170 µm long (Hoggarth 1993). Glochidia that are higher than long are mostly gill parasites. This morphological feature tends to maximize the chance of a successful encounter, while sacrificing adductor muscle strength that may be less important for maintaining attachment to this protect-

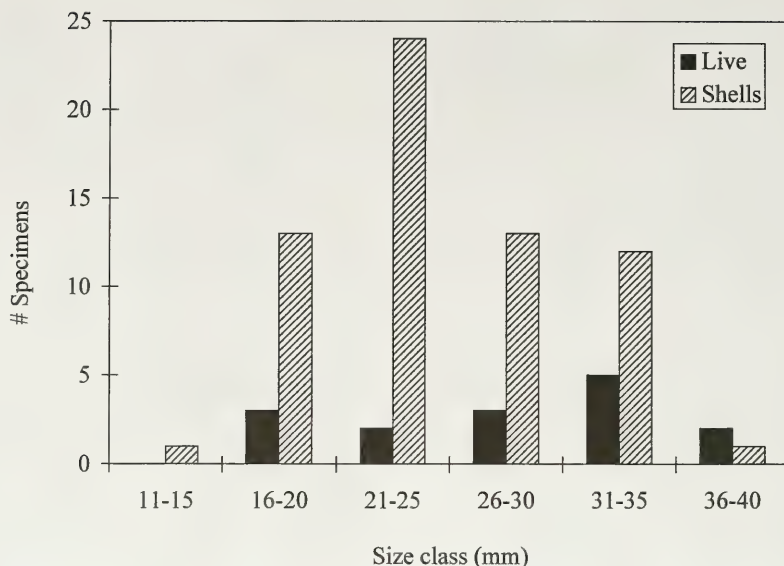


FIGURE 3. Size class distributions for live specimens and spent shells of *V. fabalis* found in the Sydenham River in 1997–1998.

ed internal surface. As *Villosa iris* is known to be a gill parasite (Jacobson et al. 1997), this is probably also true for *V. fabalis*. Most, but not all, lamprolins are gill parasites. The Northern Riffleshell, *Epioblasma torulosa rangiana*, is an example of a lamproline that is a fin parasite (Hoggarth 1993).

Only one fish host, the Tippecanoe Darter (*Etheostoma tippecanoe*), is known for *Villosa fabalis* (G. T. Watters, Ohio State University, personal communication, November 1997). As this species of fish is not found in Canada, the host fish for *V. fabalis* in this country is presently unknown. Assuming that darters are the most likely hosts, data on the distributions of darter species in the Sydenham and Thames rivers were obtained from the Royal Ontario Museum and the Ontario Ministry of Natural Resources' Ontario Fisheries Information System for comparison with the distribution of *V. fabalis* in these rivers. Nine species of darters have been found to inhabit the main stem of the Sydenham River: the Greenside Darter (*Etheostoma blennioides*), Rainbow Darter (*Etheostoma caeruleum*), Logperch (*Percina caprodes*), Eastern Sand Darter (*Ammocrypta pellucida*), Fantail Darter (*Etheostoma flabellare*), Least Darter (*Etheostoma microperca*), Johnny Darter (*Etheostoma nigrum*), Blackside Darter (*Percina maculata*), and River Darter (*Percina shumardi*). All species except the Fantail Darter and River Darter were collected live in 1997 from the stretch of the river where *V. fabalis* presently occurs. The darter community of the Thames River is almost identical to that of the Sydenham River, except that it also includes the Iowa Darter

(*Etheostoma exile*). It is likely that one or more of these fishes serve as hosts for *V. fabalis* in Canada. To confirm that a fish is a suitable host, it must be shown to facilitate the metamorphosis of glochidia in laboratory tests. Such tests have not yet been conducted in Canada.

The Rayed Bean, like all freshwater mussels, is a filter feeder. Although the exact food preferences of the adult form are unknown, they are probably similar to those of other freshwater mussels, i.e., suspended organic particles such as detritus, bacteria and algae (TNC 1986*).

Limiting Factors

Siltation, impoundments, pollutants from municipal, industrial and agricultural sources, and possibly Zebra Mussels, *Dreissena polymorpha*, have threatened *Villosa fabalis* across North America. Access to suitable fish hosts may also be a factor, but it cannot be assessed for Canadian populations until the host species have been identified. Siltation, urbanization and flood plain development have led to the deterioration of water and habitat quality for mussels in general (Biggins et al. 1995*). The historical distribution of *V. fabalis* in Ontario falls within one of the most heavily populated and intensively farmed regions of Canada. The main land use in the Thames and Sydenham River watersheds is agriculture, accounting for 80–85% of the total land area in both basins (WQB 1989, 1990). Factors limiting the occurrence of *V. fabalis* in Canada probably include siltation, due to poor agricultural practices; exposure to agricultural chemicals, such as fertilizers and pes-

ticides; highway runoff (Mackie 1996); and municipal and industrial discharges, particularly in the upper portion of the Thames River basin.

The sensitivity of *V. fabalis* to specific environmental pollutants is not known, because this species has never been subjected to toxicity testing. According to Orton-Palmer and Keller (1997), "No studies have been published, nor is any data available, on toxic effects to threatened or endangered unionid species." However, newly-released glochidia of the related species, *Villosa iris*, have been tested for their response to several common river pollutants. Goudreau et al. (1993) found that the glochidia of *V. iris* were more sensitive to ammonia (24-hour LC50 = 0.284 mg/L) and monochloramine (24-hour LC50 = 0.084 mg/L) than many other species of invertebrates, including other molluscs. Jacobson et al. (1997) determined the toxicity of aqueous copper to the released glochidia of five species of unionids, and found that *V. iris* was the second most sensitive species (24-hour LC50 = 38–80 µg/L). If *V. fabalis* is as sensitive to pollution as *V. iris*, then it is likely that toxic contaminants are at least partially responsible for reductions in the occurrence and abundance of *V. fabalis* throughout its range.

Siltation is probably the most immediate threat to *V. fabalis* in the Sydenham River, but eutrophication and pesticide inputs may also be significant factors. Cash crops, pasture and woodlot are the predominant types of agriculture in the basin (Muriel Andreae, St. Clair Region Conservation Authority, personal communication, March 1998), and there is an extensive tile drainage system (Mackie and Topping 1988). Twenty years ago, Clarke (1978) found the river to be largely unpolluted, and urged that it be made an ecological preserve so that its unique unionid community could be protected. By 1991, he observed that most of the riffles were covered in silt and many of the riffle-dwelling species were missing from his collections (Clarke 1992); thus, he attributed the loss of these species to the loss of clean riffle habitat. In a laboratory experiment, Aldridge et al. (1987) found that the intermittent exposure of several species of mussels to high levels of suspended solids (similar to what might occur after a rain event in an agricultural area) significantly altered their physiological energetics. Such metabolic changes could, in turn, affect survival rates. Metcalfe-Smith et al. (1998b, 1999) found that water clarity (measured as maximum depth at which the stream-bed was clearly visible) was poor in 1997–1998, averaging 23 cm for all sites and 19 cm for the sites where *V. fabalis* was found alive, indicating heavy suspended sediment loadings to the system.

Anthropogenic impacts on the Thames River appear to be more severe than those on the Sydenham River, and may have caused the extirpation of *V. fabalis* and several other mussel species

from the system. Thirty percent of the species historically known from the Thames River were not found alive during the surveys of 1997–1998, but only 15% of species were missing from the Sydenham River (Metcalfe-Smith et al. 1998b, 1999). Furthermore, several of the remaining species in the Thames River were represented by remnant, non-reproducing populations. Livestock farming is the main form of agriculture in the upper portion of the Thames River, whereas cash crop farming predominates in the lower Thames. While over 80% of the basin was covered in forest prior to the 1880s, only 8% was still forested in 1989. The upper Thames supports a large urban population; in 1988, there were 22 sewage treatment plants and two industries discharging their wastes into this part of the system (WQB 1989). Tile drainage systems, wastewater drains, manure storage and spreading, and insufficient soil conservation practices all contribute to the impairment of water and habitat quality in the Thames River. Soil and streambank erosion is severe, causing high suspended sediment loads. There has been a steady increase in phosphorus and nitrogen inputs to the Thames River, and some of the highest livestock phosphorus loadings for the entire Great Lakes basin are attributable to the Upper Thames watershed (WQB 1989). Despite recent efforts to improve water quality throughout the basin, poor water quality still exists in some areas. For example, mean ammonia concentrations in all sub-basins exceed the Federal freshwater aquatic life guidelines, and mean concentrations of copper exceed the guideline in several sub-basins (WQB 1989). The physical destruction of mussel habitat by cattle having access to the river is undoubtedly a significant problem in the upper reaches of the Thames.

Although human impacts have been causing the reduction and extirpation of mussel populations for many years (Nalepa and Gauvin 1988), the introduction of the Zebra Mussel to the Great Lakes in the late 1980s (Hebert et al. 1989) has led to catastrophic declines of native mussels in Lake St. Clair (Nalepa et al. 1996), western Lake Erie (Schloesser and Nalepa 1994) and the upper St. Lawrence River (Ricciardi et al. 1996). Zebra mussels now infest a large portion of the former range of *V. fabalis* in Ontario, i.e., the Detroit River and western Lake Erie. As Zebra Mussels only attach to exposed surfaces, it is unlikely that they would threaten a burrowing unionid such as the Rayed Bean.

Predation by Muskrats (*Ondatra zibethicus*) is a potential limiting factor for some mussel species (e.g., Neves and Odom 1989; USFWS 1994). In the Sydenham River, anecdotal information suggests that Muskrat predation could be a contributing factor in the decline of the endangered Northern Riffleshell (Staton et al. 2000). However, this threat can probably be ruled out as a limiting factor for *V. fabalis*.

Convey et al. (1989) and Hanson et al. (1989) found that Muskrats do not feed on mussels smaller than 35–40 mm in shell length, which is close to the maximum size reported for *V. fabalis*.

Special Significance of the Species

Of the 18 species of North American mussels that belong to the genus *Villosa*, only two (*Villosa iris* and *Villosa fabalis*) occur in Canada. Merely one-third of these 18 species are presently considered to be stable in terms of their distribution and abundance (Williams et al. 1993). The current distribution of *V. fabalis* is discontinuous (TNC 1987*). In New York, for example, it is believed to be spatially restricted to small areas that still support reasonably healthy populations (D. L. Strayer, Institute of Ecosystem Studies, Millbrook, New York, personal communication, March 1998). Such populations are difficult to locate, mainly because of the small size of the animal and its unusual burrowing habits, and even harder to manage because of their spatial separation. Although there is a general consensus that the range of the species and size of its populations are decreasing, the persistence of healthy populations in some areas suggests that it has good potential for recovery. The Sydenham River in southwestern Ontario supports the only known reproducing population of *V. fabalis* in Canada.

Evaluation

Villosa fabalis was once widely, but discontinuously distributed throughout its original range in North America. It appears to have always been rare, with seldom more than a handful of live specimens found in a day's sampling at most sites. Although population trends are difficult to quantify due to the paucity of numerical data, there is a general consensus that the species has significantly declined in distribution and abundance in recent years. *Villosa fabalis* is more difficult to find in the field than most other species of unionids because of its very small size and burrowing habits; thus, its distribution and abundance may have been somewhat underestimated. *Villosa fabalis* was previously listed as a Category 2 Federal Candidate under the U.S. Endangered Species Act, but this category is no longer used. Its global rank was uplisted from G2 to G1G2 in February 1997, and its current sub-national ranks are SX in Illinois and Virginia, S1 in Indiana, Kentucky, Michigan, New York, Pennsylvania, Tennessee, West Virginia and Ontario, and S2 in Alabama and Ohio (TNC 1997*).

There are only a few recent references to the continued existence of "reasonably healthy" populations of *V. fabalis*, and these are for several sites in western New York, northwestern Ohio, and northeastern Pennsylvania. The Sydenham River in southwestern Ontario supports the only known reproducing population of *V. fabalis* in Canada. This population

appears to be of low density and confined to a 45 km stretch of the middle section of the river, although there is evidence that recruitment is still occurring. The species appears to be extirpated from the Thames River, with little chance of being re-established because the headwaters where it once occurred are severely degraded.

Villosa fabalis's habitat requirements may not be as restrictive as those of other rare species with which it often co-occurs. For example, the Northern Riffleshell (*Epioblasma torulosa rangiana*) is confined to highly oxygenated riffle areas with rapid currents and coarse sand to fine gravel substrates, while *V. fabalis* prefers river margins and the edges of in-stream islands where it burrows among the roots of aquatic vegetation in shallow, slower-flowing zones. Such habitats are plentiful in most areas. The impact of Zebra Mussels on this species is not known, but may be insignificant. Agricultural chemicals and siltation are likely the most significant threats to the continued existence of the species throughout North America. There is some evidence that species of the genus *Villosa* may be very sensitive to environmental contaminants.

As the only remaining Canadian population of *V. fabalis* is found in the Sydenham River, where it is at continued risk of extirpation from intensifying agricultural activities in the region, it is recommended that the Rayed Bean be classified as Endangered in Ontario and Canada. This manuscript is based on the reports to COSEWIC and COSSARO, but has been updated to incorporate new data collected in 1998.

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Leadership in Wolf, *Canis lupus*, Packs

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I examine leadership in Wolf (*Canis lupus*) packs based on published observations and data gathered during summers from 1986 to 1998 studying a free-ranging pack of Wolves on Ellesmere Island that were habituated to my presence. The breeding male tended to initiate activities associated with foraging and travel, and the breeding female to initiate, and predominate in, pup care and protection. However, there was considerable overlap and interaction during these activities such that leadership could be considered a joint function. In packs with multiple breeders, quantitative information about leadership is needed.

Key Words: Wolf, *Canis lupus*, leadership, behavior, foraging, movements, pup care, provisioning, sociality, reproduction, breeding, Northwest Territories.

Leadership in Wolf packs has been addressed only a few times. Mech (1970:73) defined leadership among Wolves as "... the behavior of one Wolf that obviously controls, governs, or directs the behavior of several others" such as when Wolves decide on direction of travel, when to rest or travel, and whether to chase prey. Peterson (1977) and Haber (1977) adopted similar definitions.

However, few opportunities have existed for studying leadership in wild Wolf packs because of the elusive nature of Wolves. Only Murie (1944), Clark (1971), Haber (1977), and Mech (1988, 1995a, 1999) have studied behavior in free-ranging Wolf packs, and no one has examined the leadership concept critically or quantitatively. This article attempts to do so, based primarily on my 13 summers of observation of a free-ranging Wolf pack.

Because Wolf packs are basically families (Murie 1944; Mech 1970), or at least almost always include a breeding pair (Mech and Nelson 1990; Mech et al. 1998), it is only natural that some member of this pair would be the pack leader (Mech 1970). This is because most members of the pack would be the offspring of the breeding pair and would tend to follow their parents' initiatives. Sometimes, a post-reproductive animal remains with the pack (Mech 1995a). Conceivably, such an individual, being older and more experienced, would lead in some activities. On the other hand, deposed breeders usually become subordinate, and tend not to take initiatives involving the group (Zimen 1976). A post-reproductive female on Ellesmere was subordinate to the breeding pair (Mech 1999).

Therefore, determining which member(s) leads the pack in a given activity would usually involve determining whether it is the breeding male or breeding female. Murie (1944) identified a male "lord and master" of a pack to which all four other

adults submitted. Murie concluded that this animal was not mated to any of the females, although there was no way he could have known (Haber 1977). One of the other adult males tended to lead the chases of Caribou, *Rangifer tarandus*, during Murie's study.

On Isle Royale, Mech (1966) observed from the air that in a large pack one member stood out as leading the pack, taking the initiative during hunts, and making decisions, but Mech could not identify the individual well enough to know whether it was always the same Wolf. It did, however, seem to be a male, and during the breeding season, a female sometimes led, with a male close behind her.

Later, Jordan et al. (1967) recognized a particular male that led the Isle Royale pack during travels for several winters. On the other hand, Peterson (1977), observing the Wolves during the breeding season, believed that females tended to lead the packs, as concluded by Pulliainen (1965: 236) who cited anecdotal literature.

Haber (1977) considered a "beta male" to be the leader of the Savage Pack in Denali Park. That animal tended to break trail, set the direction and pace of travel and resting, and initiated and ended most of the hunts and rest periods. However, this pack was highly unusual in that both the alpha male and beta male remained with the pack until 8 or 9-years old. No one else has ever reported two adult males remaining concurrently with a pack for even 4 years, including during a study of 13 packs for 4–9 years in the same area (Mech et al. 1998). In two other packs, Haber believed that high-ranking males generally led pack travels. During summer, leadership was less clear but Haber believed it also tended to involve high-ranking males. None of these studies provided quantitative behavioral data on leadership.

Methods

I gathered both quantitative and anecdotal data relevant to leadership from a free-ranging Wolf pack during summers 1986 through 1998 on Ellesmere Island, Northwest Territories, Canada (80°N, 86°W). There, Wolves prey on Arctic Hares (*Lepus arcticus*), Muskoxen (*Ovibos moschatus*), and Peary Caribou (*Rangifer tarandus pearyi*), and live far enough from exploitation and persecution by humans that they are relatively unafraid of people (Mech, 1988, 1995a). During 1986, I habituated the pack of Wolves there to my presence and reinforced the habituation each summer. The pack frequented the same area each summer and usually used the same den or nearby dens. The habituation allowed an assistant and me to remain with the Wolves daily, to recognize them individually, and to watch them regularly from as close as 1 meter (Mech 1988, 1995a, National Geographic 1988). We recorded all the behavior we observed, and the following results are based on all our observations, rather than on a sample. They do, however, apply only to the pack and period studied.

Results and Discussion

Awakening and Initiating Foraging

Discerning leadership in activities preceding travel away from the den was complex. Usually the activities included awakening of individuals, their awakening of packmates, considerable socializing, and eventually travel away from the den. Even after travel began, the trip could be aborted kilometers away when a pup or pups followed, and the breeding female eventually led or carried them back to the den.

Generally pack members awaited the awakening of their parents before becoming very active, although sometimes their activity would awaken the parents. Nevertheless, it was not until the parents were awake and active that much socializing went on. Often the breeding female awoke first and tried to awaken the male. Furthermore, the female sometimes seemed to urge the male to become active and go foraging. She would lead the male away only to have him lie down again, and the two would then begin howling. After that, the two would arise and go off again, but sometimes they would repeat this behavior a few times. Eventually the pair would leave the area, and after 5 to 30 minutes the female often returned alone, as Murie (1944) also observed, apparently having sufficiently motivated the male well enough to trust that he was actually continuing on. (On the other hand, the female of another pair I observed without offspring often ignored the howling of her mate when he behaved as though he wanted to depart from a foraging area. Rather than join the standing, restless, howling male, this female would continue resting or sleeping without even

replying to his howl. For example, at 2215 hours on 6 July 1998, this male howled 48 times with no reply from the nearby female.) Each summer, as the pups got older, the female tended to accompany the male and the rest of the pack for much longer periods. Of 29 times that I was able to determine which Wolf led the Ellesmere pair or pack away from the den, the male was first 22 times and the female 7 ($\chi^2 = 4.22$; $P < .05$; 1 d.f.).

Traveling

Discerning a leader during travel can be complicated by such issues as youthful exuberance and estrus that may cause individuals that might not be directing the overall activity to sometimes surge to the head of the line of traveling Wolves. Wolves often follow river beds, game trails, and old roads. When doing so, it is obvious where the pack is headed for certain stretches, so any Wolf may forge ahead temporarily, as Murie (1944) and Haber (1977) also noted.

During the breeding season, the order of a Wolf in line as the pack travels would be influenced by the fact that the breeding female would be in estrus. Thus the breeding male generally would be behind the breeding female both to guard her from other males and to be ready for breeding (Mech 1966: 61; Peterson 1977: 71–74).

On Ellesmere Island, I followed traveling Wolves during summer (Mech 1994). Because it was often difficult to navigate the terrain and remain close to the Wolf pack, I could not always identify the first Wolf in line during their travels. Therefore, I restricted my data collecting on this subject to times when I could.

On 70 occasions when I recorded which Wolf was ahead during actual travel, the male was ahead 46 times and the female 24 ($\chi^2 = 3.54$; $P = 0.06$). Most of these travel instances were observed in 1993, when the male led 27 times and the female 8 ($\chi^2 = 5.50$; $P = 0.02$), and 1996, when the male led 14 times and the female 12 (n.s.). In 1993, there were no pups, so the pack was comprised of the breeding pair and three yearlings. The yearlings food-begged and deferred far more to the male that year than to the female (Mech 1999). In 1996, the only adult-sized Wolves were the breeding pair.

Hunting

During attacks on prey, it is the breeders that seem to initiate and press the attack. Murie (1944) documented that it was high-ranking males, and Mech (1966) showed that it was those at the head of the pack, which usually are the breeders, that led the attack on Moose (*Alces alces*) and that both parents led attacks on Muskoxen (Mech 1988; National Geographic 1988). Clark (1971) found the same for Wolves hunting Caribou. Haber (1977) stated that high-ranking males tended to lead chases most

often. Ballard et al. (1987, 1991) found that adults, especially males, led the hunts. This was also true of Coyotes (*Canis latrans*) (Gese and Grothe 1995).

Whether the breeding male or breeding female begins the attack or predominates during it probably depends on the quickly changing circumstances of a given pursuit or attack. I have known of, or observed, cases in which both breeding male and breeding female in the absence of the other have killed ungulates. Furthermore, it seems reasonable to think that any experienced member of the pack that has an opportunity to initiate an attack might do so, as Clark (1971) observed, but that ordinarily the breeders would be in the best position to initiate an attack if all of the pack members are together.

During pack hunts of Arctic Hares on Ellesmere Island, all pack members chased hares when they had an opportunity. However, during hare hunts that lasted hours and involved many hares (usually leverets), the breeding male more often ambushed and caught hares chased by the yearlings. In 1993, I watched him capture four leverets this way and relinquish them to the yearlings, whereas I only saw the breeding female catch two during the same hunt, and she tried to eat them herself (Mech 1995b).

Provisioning the Pack

Provisioning the pack includes not only hunting, as discussed above, while the pack is nomadic during fall, winter, and spring, but also delivering food to the female and pups around the summer den and rendezvous sites. The breeding male clearly dominates this activity during the first several weeks after the pups are born, for the female remains with the pups most of that time and depends considerably on the male for her own food (Mech et al. 1999). As the male approaches the den, the female rushes him solicitously. If the male is carrying food, he drops it, or the female snatches it away from him with his clear consent. If the food is in his stomach, the male regurgitates, and the female instantly consumes the regurgitant.

When the pack has no pups, then the male plays a major role in feeding the yearlings (Mech 1999). I once watched the breeding pair leave three yearlings at their rendezvous site and travel 9.5 km away, where the male then dug up a cached Muskox calf shoulder and delivered it to the breeding female. She consumed it and then immediately returned to the yearlings and regurgitated to them (Mech 1995b). This behavior appeared to be merely an extension of the breeding male's behavior of feeding the female while she tends the pups.

However, provisioning the breeding female when she is caring for the pups is a difficult activity to assess for determining leadership (Mech 1999). Is the breeding male showing leadership because he hunts and brings food back to the breeding female? Or is the breeding female displaying leadership

because she takes charge of the food from the breeding male?

Contending with Intruders at Den

During disturbances at the den, it is difficult to determine which Wolf might be leading activities because of the general turmoil by all pack members. Murie (1944) described several instances in which a pack chased Grizzly Bears (*Ursus arctos*) away from the East Fork den, and generally the high-ranking (older) males were the most aggressive and persistent. This was also true when Murie himself disturbed the Wolves. As indicated earlier, Clark (1971) observed that the breeding female was most likely to drive away intruders, but Haber (1977) observed that with his packs it was usually the alpha male.

I made one observation of the Ellesmere pack protecting their den from a disturbance in 1994 that sheds some light on the subject. The pack consisted of a breeding pair, one 2-year-old male offspring, a 2-year-old female offspring, and one 5-week old pup. All were asleep around the den when an adult male Muskox wandered over a nearby ridge to the den area. The breeding male, which was farthest away, sensed the animal first and approached it. After a flurry of activity when the others detected the Muskox, the intruder stood its ground around the den. All the Wolves excitedly circled it and approached it many different times while it stood its ground in front of the den entrance with the pup inside.

After about 1 hour, during which the pack was unsuccessful in forcing the Muskox to leave, the breeding female began barking and bark-howling. All pack members then followed her to the west of the den and Muskox, where they all sat or lay while the breeding female continued barking and bark-howling. They were positioned about 5 meters apart, with the breeding female being closest to the Muskox but still 10 meters away.

It appeared that the breeding female had suddenly realized that surrounding the Muskox was only keeping it in front of the den, so she had led the pack to one side, giving the Muskox a safe direction away from the den. After 30 minutes of the Wolves remaining to one side of the den with the breeding female bark-howling, the Muskox headed eastward away from the den. The Wolves then returned to the den, and the pup emerged. During this incident, the breeding female always approached the Muskox more closely than did the male, as she also did in a similar incident in 1996.

In five similar incidents, the male acted more aggressively toward the Muskox one time, and neither male nor female paid the Muskox much attention in the other four. With a disturbance by a strange human in 1996, the male responded most aggressively while the female led the pups away.

Interacting with Alien Wolves

I have watched breeding pairs of Wolves on Ellesmere encounter alien Wolves four times, and each time they pursued the stranger together and with apparently equal aggressiveness (Mech 1993 and unpublished). After another such encounter of which I only observed the aftermath, the breeding pair and the breeding female's post-reproductive mother were all bloody, indicating that all had participated in the attack, which ended in the death of an alien Wolf. Murie (1944) found that an adult male at a den was most aggressive towards an alien Wolf that approached, and Harrington and Mech (1979) found that it was the breeders, most often the adult male, which approached the source of strange howls.

Caring for Pups

As expected, breeding females take the initiative and clearly spend more time and effort caring for the pups than do any other pack members, even though the breeding male and all other Wolves that center around the den feed and play with them and show general concern for them (Murie 1944; Clark 1971; Haber 1977; Mech 1988; Ballard et al. 1991; Mech et al. 1999). However, the only Wolf I have ever seen carrying a pup was the mother, although I have observed a post-reproductive female attempting to do so.

Packs with Multiple Breeders

A relatively small proportion of free-ranging Wolf packs include multiple breeders. The number of pack years in which multiple females per pack produce pups are estimated at between 6% (Packard 1980) and 41% (Harrington et al. 1982). The higher figure, however, included a sample of gravid Wolves (Rausch 1967), some of which probably resorbed their fetuses eventually (Hillis 1990), and it did not include large samples of Wolf packs from studies that Packard (1980) surveyed. In Denali Park alone, where multiple litters have been much publicized (Murie 1944; Haber 1977), the actual incidence of multiple litters was 9 (8%) in 108 pack years (Mech et al. 1998).

Nevertheless, packs with multiple litters have been the subjects of three of the four observational studies of wild Wolf behavior, and in their complexity they could shed light on the simpler social structure of most packs. However, little is known about the relationships between the breeding pairs in such packs, except that most likely the female breeders are related, probably mother and daughter or mother and two daughters, with the daughters' mates being adopted males (Mech et al. 1998). Whatever the case, the breeding males are probably unrelated to their mates (Smith et al. 1997). An exception may be the Rose Creek pack reintroduced into Yellowstone National Park in 1995, in which the 2-3 breeding females during 1997 and 1998 most probably were

bred by related packmates (D. W. Smith, personal communication).

Unfortunately, no quantitative data about packs with multiple litters were obtained to allow any definite conclusions to be drawn about leadership in such packs (Murie 1944; Clark 1971; Haber 1977). One of the two breeding females Clark observed in the Nadluardjuk pack of Baffin Island dominated the other, but no other information about leadership in that pack was reported.

Conclusions

The above observations are consistent with the prevailing view that Wolf packs typically are family units, with the adult parents guiding the activities of the group and sharing group leadership in a division-of-labor system (Mech 1999) in which the female initiates primarily such activities as pup care and defense, and the male initiates primarily foraging and food provisioning and the travels associated with them. There is much overlap in the leadership activities.

Socially, the breeding pair dominate their offspring and lead their activities, and although the breeding male appears socially dominant to the breeding female (Mech 1999), he feeds the female while she nurses the pups and cooperates with her in their care and protection. As the pups age, the male seems more intent on feeding them than does the female, perhaps allowing the female to improve her nutritional condition for the next litter. Conceivably, once the female is in good enough condition, she might then contribute as vigorously to offspring provisioning as the male.

In packs with multiple litters, it seems likely that the original progenitors of the pack, being oldest, probably dominate and lead the pack. However, as the younger breeders age, they may assume more initiative and lead their own offspring independently. This is probably the best explanation for both temporary (Mech 1966; Jordan et al. 1967 but cf. Haber 1977) and permanent pack splitting (Mech 1986; Mech et al. 1998). More information about leadership in packs with multiple breeders is needed.

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Effects of Selective Hunting on Group Composition and Behavior Patterns of Pronghorn, *Antilocapra americana*, Males in Montana

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Although regulated hunting may not adversely affect wildlife populations, effects of some harvest regimes are inadequately known. We tested the assumption that a trophy Pronghorn (*Antilocapra americana*) hunt, held during the breeding season, would not alter behavior patterns or group composition of a population located at Fort Belknap Indian Reservation, Montana. We compared behavior and group composition between males from this population and a population near Billings, Montana, that was not hunted with firearms during the breeding season. Males from the two populations did not differ in time budgets or interaction rates. However, groups at Fort Belknap, where population density was higher (3.5/km² vs. 1.5/km²) contained significantly more females and fawns. Overall, a selective hunt for Pronghorn males does not appear to impact negatively the behavior patterns of these animals, probably because hunter density was low, 0.04 hunters/km².

Key Words: *Antilocapra americana*, Pronghorn, behavior, group composition, selective hunting, Montana.

In North America, hunting regulations commonly facilitate selective removal of specific age and sex classes. For example, individual hunters often are restricted to one antlered or horned animal per year unless management objectives strive to reduce the population (Robinson and Bolen 1989). This practice is not necessarily detrimental to polygynous populations because only a few males generally sire most of the young, and most males never produce offspring (Krebs and Davies 1993). By issuing permits for males, some males are removed from the population, but sufficient numbers remain to ensure all females are bred. However, trophy hunting raises concern among some biologists because trophy hunters remove animals that meet a narrow set of criteria, usually related to body, horn or antler size (Fichter and Autenrieth 1978; Ginsberg and Milner-Gulland 1994).

Justifications and assumptions of trophy hunting include: (1) the harvest of older, mature males will not affect behavior patterns, pregnancy rates, timing of breeding or parturition, neonate size or survival; (2) hunting replaces mortality due to other causes (e.g., starvation, increased vulnerability to predators, or other ailments associated with advanced age); and (3) removal of older, and perhaps less viable, males is not detrimental to the population as a whole (Peek 1986). Yet these assumptions have not been thoroughly tested (Rutberg 1997).

Males-only hunts may produce sex ratios that are skewed toward females, but skewed sex ratios may or may not lead to lowered productivity (Boyd 1970; Trainer and Lightfoot 1970). Trophy hunting might remove the largest, and presumably the most dominant, males in the population, which would allow younger, less competent males to breed (Geist 1971;

Fichter and Autenrieth 1978; Prothero et al. 1980; Heimer et al. 1984). Younger males then may experience higher mortality rates, perhaps because they engage in early reproductive activity (Jorgenson et al. 1997), and females may expend more energy as a result of harassment from inexperienced males (Geist 1971; Noyes et al. 1996). Finally, one model of an Impala (*Aepyceros melampus*) population revealed that harvesting large numbers of males (> 8% of the population) led to a long term decline in the model population because male reproduction was limited by sperm production (Ginsberg and Milner-Gulland 1994).

Concerns about selective hunting have focused primarily on polygynous species that utilize a female defense mating strategy because the effects of harvesting a dominant male affects reproduction for a large percentage of females. Therefore, biologists primarily have examined effects of hunting on Elk (*Cervus elaphus*; e.g., Noyes et al. 1996), White-tailed Deer (*Odocoileus virginianus*; e.g., Swihart et al. 1998) and Bighorn Sheep (*Ovis canadensis*; e.g., Jorgenson et al. 1997). We found only one study that directly measured impacts on Pronghorns (*Antilocapra americana*). In that study, Copeland (1980) reported that hunting Pronghorns during the breeding season disrupted normal reproductive behavior.

A search of hunting regulations in the U.S. and Canada revealed that 12 of 15 states and provinces have archery hunts, and 6 of 15 hold firearm seasons for Pronghorns that overlap the breeding season. Archery hunts probably have little effect on Pronghorn breeding systems because of lower numbers of hunters, lower success rates, and the less disruptive nature of the hunt (O'Gara and Yoakum

1992). However, firearms hunts potentially can interfere with breeding, depending on numbers of hunters participating and the time frames involved.

In 1993, the Gros Ventre and Assiniboine tribal government implemented a nontribal member trophy hunt for Pronghorns at Fort Belknap Indian Reservation in northcentral Montana. This hunt occurs from 1 September through 31 October and overlaps the breeding season, which occurs primarily during September (Kitchen 1974). A maximum of 100 nontribal member tags is sold each year, with no distinctions between resident or nonresident status. The nontribal member hunt is marketed toward providing a high quality hunting experience (i.e., the opportunity to hunt with few other hunters, a large selection of legal Pronghorns, and a good chance to harvest a trophy-quality male). No horn size restrictions are imposed, but most nonmember hunters seek and harvest larger horned "trophy" males. Gros Ventre and Assiniboine members also are allowed to hunt Pronghorns during this time using the same methods as nonmembers, but interest is low. Harvest by tribal members is limited (about 250/year) and focuses on females; members rarely harvest trophy males (< 10/year; M. Fox, Fort Belknap Fish and Game Department, personal communication). Because little information is available on the impacts of hunting Pronghorns during the breeding season, the Gros Ventre and Assiniboine government wanted to ensure that the trophy hunt had no negative impacts on the Pronghorn population.

The primary objective of this study was to determine the impacts of a selective hunt, held during the breeding season, on behavior patterns of Pronghorn males. We compared activity budgets, interaction rates, and group composition in the hunted population at Fort Belknap to a Pronghorn population near Billings, Montana. The Billings population was used as a control site because one of us (C. R. Maher) already had studied the population for several years and because it received no firearms hunting pressure during the breeding season. Since few hunters were present on the Fort Belknap Indian Reservation at any given time and because few tags were sold relative to the total population size of Pronghorns, we predicted hunting pressure would not alter activity patterns, increase interaction rates, or change group composition.

This hunt also provided the opportunity to study the effects of a management policy using a hypothetico-deductive approach (McNab 1983; Sinclair 1991; Lancia et al. 1996). Available funding and personnel limited study length; however, the results provide additional data for Pronghorn managers to use to develop management prescriptions.

Study Areas and Populations

Although the two study areas were not identical, they were similar to each other in several ways

(Table 1). Fort Belknap Indian Reservation encompasses approximately 272 000 ha in northcentral Montana, at 48°N and 108°40'W. Native vegetation is a mixed prairie community intermingled with Wheat (*Triticum aestivum*) fields and land set aside in the Conservation Reserve Land Program (CRP; C. D. Mitchell, U.S. Fish and Wildlife Service, unpublished report). In July 1996, aerial line transect surveys (Johnson et al. 1991) were used to estimate the total population size at 9550 Pronghorns (95% C. I. = 4 951 – 18 358), for a density of 3.5 Pronghorns/km² (1.8 – 6.8/km²). Sex ratios also were calculated from aerial composition counts. In July 1996, the male:female sex ratio was 25:100 (C. D. Mitchell, U.S. Fish and Wildlife Service, unpublished reports).

If all hunters were present at one time at Fort Belknap, hunter density would have been 25 km²/hunter, but approximately 66% of hunters were present during the breeding season. Based on reports from guides, we estimated an average of two hunters per day for the first seven weeks of the season. Therefore, daily hunter density was estimated at 1429 km²/hunter, if hunters were distributed equally across all Pronghorn habitat. Most hunters used rifles, and hunter success rates were 99.6% over the first four years of the program (M. Fox, Fort Belknap Fish and Game, personal communication). Hunters spent from 2 to 9 days in the field; the median number of days was 4. The number of males harvested during 1994 – 1996 ranged from 3.8% to 7.2% of the estimated male population.

The second study population occurred on the Bar Diamond Ranch near Billings, Montana, 45°53'N and 108°36'W. This area encompasses approximately 6 500 ha of native mixed prairie (Table 1). During July and September 1996, standard aerial trend and composition counts (O'Gara and Yoakum 1992) and ground based counts provided a population estimate of 100 animals (1.5/km²; C. R. Maher, unpublished data; C. Eustace, Montana Department of Fish, Wildlife and Parks, unpublished report) and a male:female sex ratio of 33:100 (C. Eustace, Montana Department of Fish, Wildlife and Parks, personal communication). The two study areas were managed by different government agencies, and agency personnel used different techniques to monitor population density and sex ratios. However, densities and sex ratios observed on both study areas were within normal ranges for Pronghorn populations (O'Gara and Yoakum 1992).

Access to the Bar Diamond Ranch was permitted only through locked gates, and the owner strictly controlled hunter numbers. During the breeding season, we estimated that Bar Diamond received 0.07 hunters/day and had a daily hunter density of 1000 km²/hunter. Hunting at this time was restricted to archery hunting only. Hunting with firearms did not begin until October, after the breeding season, and hunter numbers again were strictly controlled

during this season. Our observations ceased once the general season began.

At Fort Belknap, hunting off the reservation did not begin until October, and our observations ended in late September. Hunting was not permitted on Fort Belknap during the general statewide season; therefore, that season did not affect our study population.

Both study areas had similar, but not identical, plant communities dominated by native wheatgrasses (*Agropyron* spp.), Needlegrass (*Stipa spartea*), Needle and Thread Grass (*Stipa comata*), and native legumes (Ross and Hunter 1976); they differed primarily in the extent of Wheat fields, CRP lands, and sagebrush (*Artemisia* spp.). Pronghorns in both areas had access to Alfalfa (*Medicago sativa*) fields. Most land use practices were similar, e.g., Cattle (*Bos taurus*) grazing and growing Alfalfa. Fort Belknap contained more Wheat fields, but most Pronghorns did not use those areas extensively during the study period; rather, they typically occupied pastures and CRP lands (C. D. Mitchell, U.S. Fish and Wildlife Service, unpublished report). At Bar Diamond, most Pronghorns also were found in grasslands and Alfalfa fields.

Methods

From early May through early October, 1996, we identified individual males using natural markings, including horn characteristics, neck banding patterns, facial coloration, and tail markings (Kitchen 1974). To locate Pronghorns, we drove paved and unpaved roads that passed through the study areas. We stopped periodically to scan areas with binoculars so we could detect animals that were bedded or harder to see among the grasslands. Observations occurred from dawn to dusk at Fort Belknap. Observations occurred primarily from dawn to 1200 and from 1500 to dusk at Bar Diamond. We scheduled our observations at both study areas so each

area was searched and sampled with approximately equal frequency. We made most observations from a vehicle because the animals were less likely to flee from a vehicle compared to a person on foot. One of us (C. R. Maher) conducted observations at both study sites, so we are confident our techniques were consistent. Furthermore, we often worked together at Fort Belknap, especially early in the study period, to ensure that our techniques were identical.

Upon locating an adult male Pronghorn, we recorded his identity and group composition (i.e., number of adult males, yearling males, adult females, and fawns) if other Pronghorns were present. We recorded activity budgets for a maximum of 30 min, using focal animal sampling and continuous recording (Martin and Bateson 1993). We initiated data collection after the animal returned to the activity in which he was engaged prior to our arrival. We used binoculars and spotting scopes because we often made observations from distances estimated at 0.2 – 1.2 km. Males had to remain in view at least 5 min for the sample to be included in the data analysis. We recorded the amount of time males spent walking, standing, running, scent marking, feeding, and reclining. These variables were converted to percentages because males were not always in view for the entire 30 min. We also recorded the number of times the focal male performed a linked urination-defecation (LUD), which marks an individual's home range, and the number of snort wheezes, a vocalization associated with territorial behavior and which can be detected from a distance by distinctive movements of the male's chest (Kitchen 1974). These variables were converted to rates (number occurring per unit time). During the sample, we also recorded any interactions with other Pronghorns, both within and between sexes. If > 1 male was present in the group, we randomly selected focal animals from those in view and continued to sample

TABLE 1. Characteristics of study areas and Pronghorn populations at Bar Diamond Ranch and Fort Belknap Reservation, 26 August – 30 September 1996.

Characteristic	Bar Diamond population	Fort Belknap population
Size of study area (ha)	6 500	272 000
Plant communities	mixed prairie, CRP lands, Alfalfa fields	mixed prairie, CRP lands, Alfalfa fields, Wheat fields
Population size	100	9550
Population density (km ⁻²)	1.5	3.5
Sex ratio (male:female)	33:100	25:100
Estimated mean number of hunters/day	0.07	2
Daily hunter density (km ² /hunter)	1000	1429
Type of hunting permitted during breeding season	archery only	archery, firearms

TABLE 2. Mean activity and interaction variables for Pronghorn males at Bar Diamond and Fort Belknap, Montana during the breeding season, 26 August - 30 September 1996.

Variable	Bar Diamond population (<i>n</i> = 27 males)		Fort Belknap population (<i>n</i> = 43 males)	
	Mean	SE	Mean	SE
Active (%)	53.36	4.35	51.04	2.30
Recline (%)	12.82	3.81	11.35	2.19
LUD (hr ⁻¹)	1.90	0.35	2.95	0.38
Snort wheeze (hr ⁻¹)	0.74	0.28	0.23 ^a	0.12
Male - male interactions (hr ⁻¹)	2.74	0.79	1.73	0.48
Male - female interactions (hr ⁻¹)	10.35	2.38	15.21	2.24

^aMann Whitney *U* test: *P* < 0.05.

until all males were selected or the group moved out of view. No individual was sampled more than once in a 24-hr period.

We created a composite variable, "active", that was the sum of time spent walking, running, feeding and scent marking. We also totaled the number of interactions between the focal male and other males (e.g., displacements, chases) and between the focal male and females (e.g., herding, courtship displays), and we converted each value to a rate variable. We then calculated mean rates of interactions and percent time spent in various activities for each individual male during the breeding season, which we defined as 26 August - 30 September, based on occurrence of courtship behavior patterns. We only used data from males sampled more than once during the breeding season. The activities and groups of individually recognized males constituted the independent sampling units used in the analysis.

Because data were not normally distributed, we performed nonparametric tests using the statistical package Systat (Systat, Inc. 1992), with significance levels set at *P* ≤ 0.05. When results were not statistically significant, we performed power tests (Cohen 1988). Statistical power is the probability of finding significant results when a real effect occurs in the population (Thomas and Krebs 1997). Power tests enable us to determine if nonsignificant results are due to problems in the study design (e.g., inadequate sample size) or if the results actually indicate no biologically real effect (Thomas and Krebs 1997). Although we conducted these tests retrospectively, we provide information on effect sizes (*d*) and sample sizes (Steidl et al. 1997).

Results

Males at Fort Belknap and Bar Diamond did not differ in the percentage of time they were active (*P* = 0.34) or reclining (*P* = 0.49) during the breeding season, nor did they differ in rates of LUD (*P* = 0.09, Table 2). Power was low (0.10 - 0.67) for these tests, partially because effect sizes were small (*d* = 0.10 - 0.60). Males at Bar Diamond snort wheezed

at higher rates than males at Fort Belknap (Mann Whitney *U* test: *U* = 707.5, *P* = 0.017, *n* = 27, 42 males, respectively).

Males did not differ in mean rates of interactions with other males (*P* = 0.47) or with females (*P* = 0.09, Table 2). Power was 0.24 and 0.36, respectively. To detect large differences (*d* = 0.8, so the two population means are well separated; Cohen 1988) between the populations with power = 0.80, we needed sample sizes of at least 26 males in each population (Cohen 1988), which we exceeded.

The number of animals in a focal male's group varied between populations (Table 3). Total group size was significantly larger at Fort Belknap (*U* = 194, *P* < 0.001). Males at Bar Diamond had greater numbers of adult males in their groups (*U* = 724.5, *P* = 0.04), whereas males at Fort Belknap had greater numbers of females (*U* = 218, *P* < 0.001) and fawns (*U* = 150, *P* < 0.001) in their groups.

Discussion

Although the study areas were not identical, plant communities and land use practices were similar. The Pronghorn populations also were not identical demographically; sex ratios and population densities differed somewhat. However, a key difference between the two populations was the presence of trophy hunters during the breeding season at Fort Belknap. The Bar Diamond population experienced no firearm hunting pressure until after the breeding season ended. Despite these differences in hunting pressures, Pronghorn males from the two populations displayed similar time budgets and interaction rates during the breeding season. Thus, males at Fort Belknap did not appear to respond negatively to hunter presence. Males at Bar Diamond snort wheezed at higher rates, although population density was lower, which suggests Bar Diamond males were more territorial than Fort Belknap males (Maher 1994), perhaps as a result of more abundant and (or) more nutritious food resources (Maher, in press). However, during the breeding season, territoriality waned (C. R. Maher, unpublished data). Males in

TABLE 3. Mean number of Pronghorns in each category for focal male groups at Bar Diamond and Fort Belknap, Montana during the breeding season, 26 August – 30 September 1996.

Age or sex class	Bar Diamond population (n = 27 males)		Fort Belknap population (n = 43 males)	
	Mean	SE	Mean	SE
Adult males	1.39	0.10	1.17 ^a	0.05
Yearling males	0.34	0.17	0.19	0.06
Females	1.55	0.41	4.65 ^b	0.48
Fawns	0.53	0.13	3.53 ^b	0.40
Total group size	3.80	0.49	9.53 ^b	0.81

^a $P < 0.05$ ^b $P < 0.001$

both populations adopted a female defense mating strategy (Maher 1994).

Fort Belknap Pronghorns may not respond to hunters because they have habituated to people with firearms, specifically Black-tailed Prairie Dog (*Cynomys ludovicianus*) shooters, and the sound of shooting. Prairie Dog shooting is common across most Pronghorn habitat in Montana where the two species are sympatric. In many range units in which hunters can harvest Pronghorns, people engage in sport shooting of Prairie Dogs under a permit system operated by the Fort Belknap Fish and Game Department. In 1996, nearly 8000 people received permits (T. Vosburgh, Fort Belknap Fish and Game Department, personal communication). Shooting occurs year round, but the heaviest use occurs from late April through June (M. Fox, Fort Belknap Fish and Game Department, personal communication). Pronghorns may be accustomed to this common, predictable activity that is not harmful (to Pronghorns). One of us (C. D. Mitchell) observed a male feeding when someone started shooting < 1 km away. The male appeared unperturbed and bedded while the shooting continued. Therefore, when the breeding season begins, males may not be unduly disturbed (until they are shot at) by the arrival of Pronghorn hunters.

Group composition differed between the two populations, probably due to differences in population densities and sex ratios. Population density was higher at Fort Belknap, perhaps because quality habitat was more extensive or because overall hunting pressure in the surrounding region was lighter after the breeding season; so we expected to see larger groups there. Groups were larger at Fort Belknap during the breeding season because males had more females and fawns in their groups compared to males at Bar Diamond. Groups at Bar Diamond contained more adult males, but Bar Diamond also had a higher male:female ratio than Fort Belknap. Females were scarce, so when females were present in an area, more males congregated in those areas on Bar Diamond. Fawn recruitment also was higher at Fort

Belknap during our study, which could be due to environmental conditions, higher habitat quality, lower predator density, higher population density that in turn increased predator swamping, or some combination of these or other factors.

Although the study lasted for one field season, our data indicate that males subjected to low hunting pressure during the breeding season do not alter their behavior patterns as a result of hunting. Results similar to ours were reported from a Dall Sheep (*Ovis dalli*) population that experienced moderate hunting pressure (i.e., legal rams had $\geq 7/8$ curl, and not all those rams were harvested). In that study, Singer et al. (1991) found no significant differences in female responses to males' approaches, although females from the hunted population tended to exhibit higher numbers of responses.

Only one study has examined explicitly the effects of hunting on Pronghorn behavior patterns. In Idaho, a nontrophy hunt during the breeding season disrupted the spacing system of Pronghorn males (Copeland 1980). During opening weekend, hunter density was 0.25/km² and 0.23/km² in 1978 and 1979, respectively. By the end of the season, hunters had killed 29% and 32% of the territorial males in those two years. As a result of hunter activity, males abandoned territories and formed large, mixed sex groups. Females were not protected from male harassment as in territorial situations, and interaction rates increased four- to five-fold, perhaps subjecting animals to greater stress from energy expenditures prior to winter, the most critical period for adult Pronghorn survival (Copeland 1980).

Our results are contrary to what Copeland (1980) reported for Pronghorns in Idaho, but our study examined a different range of hunting intensity than Copeland's study. Not only were fewer hunters present at any one time at Fort Belknap, but they were distributed over a larger area. For example, during opening weekend of one year, the Idaho study area held 120 hunters, 186 companions without permits, 42 camps and 123 vehicles, all within 480 km². Hunter density alone was 0.25/km². At Fort Belknap,

even if all hunters were present at one time, which they were not, the maximum number of hunters would be 100, plus their guides and other companions, and they potentially were dispersed over 2500 km² of Pronghorn habitat, yielding a density of 0.04 hunters/km². Furthermore, people arrived over a period of two months to hunt Pronghorns. Therefore, hunting pressure was much lower at our study sites and appeared much less disruptive to the Pronghorn population.

Although hunting pressure on the reservation was lower than traditional trophy management levels, results show that some level of trophy harvest is compatible with maintenance of desirable population parameters and normal behavior patterns, thus fulfilling one assumption of trophy hunting. However, the population may be affected in other ways. Although a limited number of tags were sold, more males may have been shot than were reported, and some animals may have died later from wounds. If a hunter killed an animal that did not 'measure up,' he may have abandoned that animal for another try. Due to the mandatory presence of guides, such losses would have been minimal, but three male carcasses were found that were shot and left untouched, suggesting some level of abandonment, vandalistic shooting, or crippling loss.

When a large percentage of males is harvested, all females may not be bred (Ginsberg and Milner-Gulland 1994). At Fort Belknap, however, only 1% of the estimated population was killed during the trophy hunt. Therefore, ample males presumably remained to breed females. Female:fawn ratios were favorable (O'Gara and Yoakum 1992), varying from 100:86 in September 1994 to 100:71 in January 1995, 100:86 in July 1995 and 100:71 in July 1996 (C. D. Mitchell, U.S. Fish and Wildlife Service, unpublished reports). These values suggest productivity is not adversely affected by the hunt.

How much hunting can a population withstand before hunting changes animals' behavior patterns or population ecology? Copeland's study suggests that 0.25 hunters/km² exceeds the upper limit because that density disrupted spacing systems and increased male-female interaction rates dramatically. This study provides a lower limit, 0.04 firearm hunters/km². Lower hunter densities intuitively are less disruptive to populations, but Pronghorn managers at present cannot say at what density selective hunting pressure becomes a problem. Our figure could be revised upward if future studies showed that higher hunter densities still did not affect behavior adversely. This lower limit probably will differ among areas based on breeding behavior (Maher 1994, in press), habituation or acclimation to human activity (Geist 1971), habitat and topography, and hunting techniques permitted (e.g., use of all-terrain vehicles).

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The Status of the Dwarf Wedgemussel, *Alasmidonta heterodon*, in Canada*

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The watershed of the Petitcodiac River, New Brunswick, is the only recorded location of the Dwarf Wedgemussel, *Alasmidonta heterodon* (Lea 1830), in Canada. The species was last collected in the Petitcodiac watershed in 1960, at which time it was considered to be common in the freshwater reaches of the Petitcodiac River and one of its major tributaries, the North River. Surveys in 1984, 1997 and 1998 failed to detect any specimens and the Dwarf Wedgemussel was classified as Extirpated by the Committee on Status of Endangered Wildlife in Canada (COSEWIC) in April 1999. The disappearance of the species from Canadian waters was probably caused by the construction of a causeway across the tidal portion of the Petitcodiac River in 1967-1968 and resultant exclusion of a diadromous fish species required for completion of the glochidial stage of the Dwarf Wedgemussel's lifecycle. Local extirpations of the Dwarf Wedgemussel from much of its American range have also been linked to dam construction, which blocked migration of anadromous fishes.

Key Words: Dwarf Wedgemussel, *Alasmidonta heterodon*, Bivalvia, Mollusca, extirpated, status, Petitcodiac River, New Brunswick.

The watershed of the Petitcodiac River, New Brunswick, is the only recorded location of the Dwarf Wedgemussel, *Alasmidonta heterodon* (Lea 1830), in Canada. The species was last collected in the Petitcodiac River system in 1960, at which time it was considered to be common in the freshwater reaches of the Petitcodiac River and one of its major tributaries, the North River (Clarke 1981a,b). It has been extirpated from more than 70% of its range in the USA and was declared endangered in the USA in 1990. All but one of the remaining American populations are believed to be in decline (U.S. Fish and Wildlife Service 1993; Strayer et al. 1996).

Recent literature assumes that the Canadian population is also extirpated (Master 1986; U.S. Fish and Wildlife Service 1993; Strayer et al. 1996). Damming of rivers has been a major factor implicated in the disappearance of this species throughout its American range (U.S. Fish and Wildlife Service 1993; Michaelson and Neves 1995; Strayer et al. 1996). The Petitcodiac River was dammed in 1967-1968 with the construction of a causeway that severely impeded passage of diadromous fishes.

This report describes the results of an extensive watershed-wide survey designed to detect the presence of the Dwarf Wedgemussel in the Petitcodiac

River in 1997-1998, and summarizes our current knowledge of the status of the species in Canada.

Description

Clarke (1981b) describes the Dwarf Wedgemussel (Figure 1) as follows: "Shell up to about 45 mm long, 25 mm high, 16 mm wide, and with shell wall about 1 mm thick in the mid anterior region; more or less ovate or trapezoidal, roundly pointed posteriorly, thin but not unduly fragile, with rounded posterior ridge, and of medium inflation. Females more inflated posteriorly than males. Sculpturing absent except for lines of growth and beak sculpture. Periostracum brown or yellowish-brown, and with greenish rays in young or pale-colored specimens. Nacre bluish or silvery white, and iridescent posteriorly. Beak sculpture composed of about 4 curved ridges, which are angular on the posterior slope. Hinge teeth small but distinct; pseudocardinal teeth compressed, 1 or 2 in the right valve and 2 in the left; lateral teeth gently curved and reversed, that is, in most specimens, 2 in the right valve and 1 in the left."

The Dwarf Wedgemussel is unique in that it has two lateral teeth in the right valve and one in the left. In contrast, other species of the genus *Alasmidonta* have two lateral teeth in the left valve and one in the right.

Distribution

The Dwarf Wedgemussel has been recorded in 17 eastern North American coastal river systems from North Carolina to the Connecticut River in Vermont,

*Classified as Extirpated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in April 1999. This paper is based on the status report submitted to COSEWIC.

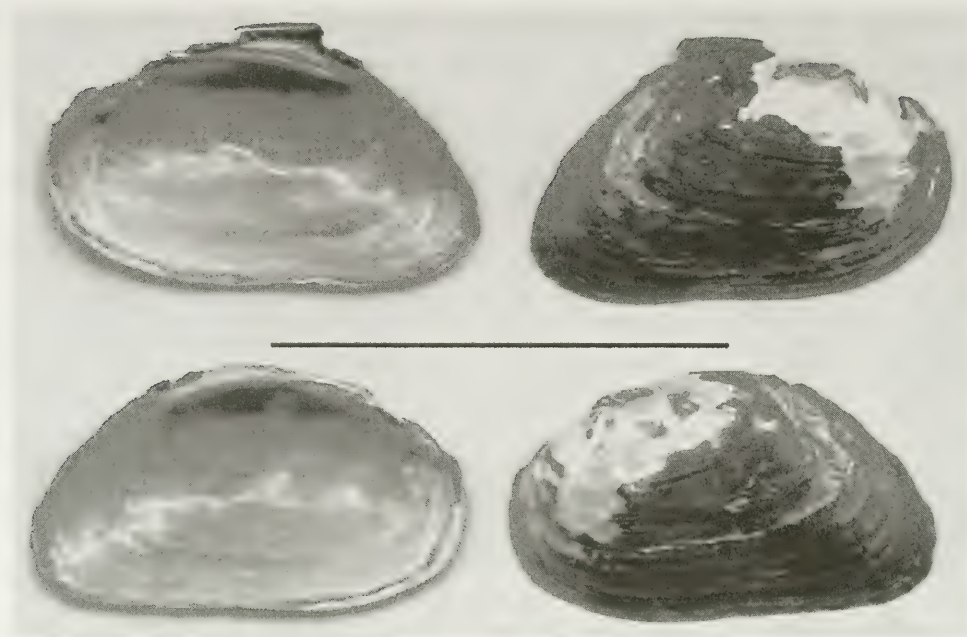


FIGURE 1. Dwarf Wedgemussel, *Alasmodonta heterodon*. The scale line is 4 cm. These specimens were collected as empty shells from the Connecticut River by D. Strayer, Institute for Ecosystem Studies, Millbrook, New York 12545, USA.

and in the Petitcodiac River in New Brunswick (Figure 2). There are no records of the Dwarf Wedgemussel in the state of Maine or any of the rivers, other than the Petitcodiac, flowing into the Bay of Fundy (U.S. Fish and Wildlife Service 1993).

The species range in Canada is restricted to the Petitcodiac River System. Based on collections by H. D. Athearn in 1953 and A. H. Clarke in 1960, the Dwarf Wedgemussel was common in the freshwater reaches of the Petitcodiac and one of its major tributaries, the North River (Clarke 1981a,b). The recent literature (e.g., Master 1986; U.S. Fish and Wildlife Service 1993; Strayer et al. 1996) assumes the Canadian population to be extirpated. We confirm this presumed extirpation (see Population Size and Trend).

Protection

This species has to date received no special protection in Canada. It is listed as Endangered in the United States and a recovery plan has been developed (U.S. Fish and Wildlife Service 1993).

Population Sizes and Trends

The Dwarf Wedgemussel has declined in, or been extirpated from, many areas of its North American range. It has always been described as uncommon to rare across most of its distribution. Of 70 known historical locations in North America, only 20 still sup-

port populations of the Dwarf Wedgemussel. All but one of the extant populations are thought to be in decline (U.S. Fish and Wildlife Service 1993). Densities range between <0.01 and 0.05 animals/m² (Strayer et al. 1996).

The Dwarf Wedgemussel was described as "common" in the Petitcodiac watershed by Clarke (1981a,b) based on his own survey in 1960. Clarke and D. McAlpine (New Brunswick Museum, Saint John) subsequently conducted a survey in 1984 specifically to detect this species but no specimens were found (see below). We conducted comprehensive surveys in 1997 and 1998 with the same negative result (see below). Therefore, the population trend is from "common" in 1960 to "undetected" in 1984, 1997 and 1998. We conclude that the Dwarf Wedgemussel has been extirpated from Canadian waters.

Summary of recent surveys

The 1984 survey: The 1984 survey used the timed-search method, which offers excellent detection of rare species (Strayer et al. 1997). Each of 12 sites (Table 1) was searched for 0.5 to 1.0 hours by A. H. Clarke and D. McAlpine between 27 and 29 August 1984 (D. McAlpine, New Brunswick Museum, Saint John, personal communication). Dwarf Wedgemussels were not found at any of the sites, despite suitable habitat conditions and the presence of freshwater mussel species known to coexist with this species.

TABLE 1. Summary of presence (P) and absence (0) of *Alasmidonta heterodon* at survey sites in the Petitcodiac River watershed, ordered from downstream to upstream locations. Positions of headpond sites were determined by an Eagle Global Positioning System. Positions of river sites were obtained from Energy, Mines and Resources Canada 1:50 000 scale topographic maps of Moncton (21-I/2, edition 4), Salisbury (21-I/3, edition 3), Petitcodiac (21-H/14, edition 3), and Hillsborough (21-H/15, edition 3). "N/D" indicates sites not searched. "N/A" indicates site did not exist at the time of the survey (headpond sites were part of the brackish tidal river in 1960). "?" indicates we do not know whether site was searched. Sites are ordered within tributary from downstream to upstream locations. Distance searched refers to the 1998 survey and is indicated as "E" for headpond sites sampled by Ekman grab.

River	Site (access point)	Latitude (DD MM)	Longitude (DD MM)	Distance Searched (m)	Year of survey			
					1960	1984	1997	1998
Petitcodiac River								
	Headpond site K	46 04.33	64 48.88	E	N/A	N/D	0	0
	Headpond site J	46 03.08	64 52.36	E	N/A	N/D	0	0
	Headpond site I	46 03.15	64 52.91	E	N/A	N/D	0	0
	Headpond site H	46 02.92	64 53.87	E	N/A	N/D	0	0
	Headpond site G2	46 03.08	64 54.69	E	N/A	N/D	0	0
	Headpond site G	46 03.32	64 54.54	E	N/A	N/D	0	N/D
	Headpond site F	46 03.36	64 56.13	E	N/A	N/D	0	0
	Headpond site E	46 03.10	64 57.52	E	N/A	N/D	0	N/D
	Headpond site D	46 02.82	64 58.08	E	N/A	N/D	0	N/D
	Headpond site C	46 02.91	64 58.92	E	N/A	N/D	0	N/D
	Headpond site B	46 02.58	65 00.07	E	N/A	N/D	0	N/D
	Headpond site A	46 01.86	65 00.74	E	N/A	N/D	0	N/D
	Former head of tide	46 01.95	65 00.75	1100	?	N/D	0	0
	Railway bridge	46 01.76	65 01.21	300	?	N/D	N/D	0
	Little River mouth	46 01.64	65 01.62	750	?	N/D	N/D	0
	Salisbury bridge	46 01.35	65 02.08	900	?	0	0	0
	French Brook	46 00.93	65 03.85	1080	?	0	N/D	0
	Pollett River mouth	46 00.15	65 04.00	250	?	N/D	N/D	0
	Covered bridge	45 59.84	65 05.56	310	?	N/D	N/D	0
	River Glade	45 58.84	65 06.67	950	P	0	N/D	0
	Petitcodiac	45 56.41	65 10.77	650	?	N/D	0	0
	Anagance River mouth	45 55.76	65 11.19	1050	?	0	N/D	0
North River								
	Glenvale	45 56.32	65 11.94	815	?	N/D	N/D	0
	Intervale	45 57.68	65 12.00	1040	?	0	0	0
	Fawcett	45 59.35	65 11.94	750	?	0	0	0
	Scott Settlement	46 02.05	65 08.67	500	?	N/D	N/D	0
	McLeod Brook	46 03.04	65 06.88	270	?	N/D	N/D	0
	2 nd North River cemetery	46 03.54	65 05.98	1300	?	0	0	0
	Upstream Route 112 bridge	46 03.92	65 05.54	350	P	0	N/D	0
	Back Road bridge	46 04.73	65 04.35	550	?	N/D	N/D	0
	Upper North River	46 04.78	65 01.65	310	?	N/D	N/D	0
Bennett Brook								
	At mouth	45 57.54	65 12.13	155	?	N/D	N/D	0
Holmes Brook								
	Town of Petitcodiac	45 55.49	65 11.19	200	?	N/D	N/D	0
Anagance River								
	At mouth	45 55.65	65 11.29	500	?	N/D	N/D	0
	1 km upstream of mouth	45 55.14	65 11.88	310	?	N/D	N/D	0
	2 km upstream	45 54.89	65 11.96	300	?	N/D	0	0
Turtle Creek								
	Route 112 bridge	46 02.68	64 52.54	300	?	0	0	0
	Above former head of tide	46 01.74	64 52.31	700	?	N/D	0	0
	Below Turtle Creek reservoir	46 00.41	64 52.05	350	?	N/D	N/D	0
Little River								
	At mouth	46 01.57	65 01.63	250	?	N/D	N/D	0
	Below Route 112 bridge	46 01.30	65 01.40	180	?	N/D	N/D	0
	Above Route 112 bridge	46 01.05	65 01.13	680	?	0	0	0
	Route 895 bridge	46 00.34	64 59.02	662	?	N/D	0	0
	Wilson Road	45 53.54	64 58.31	720	?	N/D	N/D	0

continued

TABLE 1. *continued*

River	Site (access point)	Latitude (DD MM)	Longitude (DD MM)	Distance Searched (m)	Year of survey			
					1960	1984	1997	1998
Little River (<i>continued</i>)								
	Nixon Settlement	45 57.37	64 57.50	1500	?	N/D	0	0
	Parkindale	45 54.00	64 59.23	470	?	N/D	0	0
	Parkindale 2	45 51.84	64 59.73	250	?	N/D	N/D	0
	Intervale Road	45 50.62	64 59.81	535	?	N/D	N/D	0
	Rafe Road	45 50.16	64 59.80	390	?	N/D	N/D	0
	Nowlan Road	45 49.15	64 59.80	660	?	N/D	N/D	0
	Hillside reservoir	45 45.92	65 02.08	150	?	N/D	N/D	0
Prosser Brook								
	Village of Prosser Brook	45 51.74	64 58.94	150	?	N/D	0	0
Pollett River								
	at mouth	45 59.74	65 05.42	850	?	0	N/D	0
	Kay Settlement	45 58.36	65 05.12	745	?	0	0	0
	Route 905 Glades Road	45 54.38	65 05.25	700	?	N/D	0	0
	Harrison Settlement	45 53.30	65 05.69	590	?	N/D	N/D	0
	Route 895	45 48.74	65 06.39	300	?	N/D	N/D	0
	Gordon Falls	45 46.66	65 05.71	200	?	N/D	N/D	0
	Church Corner	45 45.30	64 04.75	210	?	N/D	N/D	0

The 1997–1998 survey: We conducted a watershed-wide survey of freshwater mussels in the Petitecodiac River and its tributaries from 23 July to 21 October

1997 and 2 June to 28 August 1998. We used visual searches to investigate 47 sites in the watershed and Ekman grabs to sample four depths at each of 12 stations in the impoundment created by the causeway (Table 1).

Visual searches were conducted by surveying the full width of the river with a team of two to three searchers. In 1997, we conducted timed searches (one to two hours, two searchers). In 1998, we used a 50 m tape measure or a metered thread-dispensing device (Chainman II, Chainman Inc., Vancouver, British Columbia) to measure the distance searched, and did not restrict the time spent at each location. The stream length searched ranged from 150 to 1500 m (median 518 m; quartiles 300 and 750 m; total stream length searched 26.2 km; Table 1) and stream width varied between 3 and about 50 m. All stream banks and sand or gravel bars were carefully searched for empty shells. Water clarity was excellent at all locations. All submersed habitat was carefully searched visually and by digging in sand and gravel around rocks and boulders. Locations with large deposits of sand and fine gravel were sampled with a 30 cm wide push net (each sample represented about 0.25 m², to a depth of 5–6 cm), and sieved through the 6 mm mesh netting. This method was even more sensitive than timed searches for detecting rare species as indicated by the fact that very small juveniles (as small as 7 mm shell length) of several freshwater mussel species were collected. These small specimens were not detectable by standard timed-search methods.

We sampled 11 stations in the impoundment (between the Moncton-Riverview causeway and the Salisbury railroad bridge) in August 1997 and five

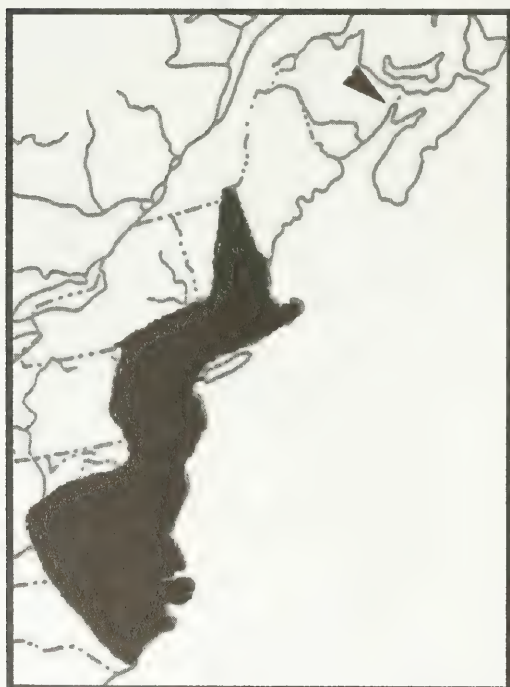


FIGURE 2. Map showing the historical distribution of the Dwarf Wedgemussel, *Alasmidonta heterodon*, in North America. The Petitecodiac River is indicated with an arrow.

stations in August 1998 (Table 1). Stations in the impoundment were sampled quantitatively with a $23 \times 23 \times 23$ cm Ekman dredge, 10 dredge hauls per sample, three samples at each of 1, 2, 3, and >4 m depths. Sediments were washed on a 6-mm sieve.

The Dwarf Wedgemussel was not detected at any sites in the watershed or the headpond nor were any shells recovered along the shoreline or on sand and gravel bars.

Habitat

The habitat requirements of the Dwarf Wedgemussel have been well documented in recent years (e.g., U.S. Fish and Wildlife Service 1993; Strayer and Ralley 1993; Michaelson and Neves 1995). The Dwarf Wedgemussel lives in running waters of all sizes, from streams <5 m wide to shallow rivers >100 m wide, usually where currents are moderate to slow. It occurs in patches of sand or fine gravel and shows very low tolerance for suspended silt or low oxygen conditions (Master 1986; U. S. Fish and Wildlife Service 1993). It is often found near river banks under overhanging trees (Clarke 1981a).

Suitable habitat for Dwarf Wedgemussel is common throughout the Petitcodiac watershed with the exception of the Pollett River. Areas of sand or fine gravel with very little suspended silt and moderate current were present in many areas of the Petitcodiac River, the Anagance River, and lower sections of the Little River. The substrate in most of the Pollett River is not suitable for the Dwarf Wedgemussel because it consists primarily of rock and large cobble with very few patches of finer substrate. Elsewhere, the Dwarf Wedgemussel is usually found in association with the Eastern Elliptio (*Elliptio complanata*), Eastern Pearlshell (*Margaritifera margaritifera*), Brook Floater (*Alasmidonta varicosa*), and Triangle Floater (*A. undulata*) (Clarke 1981a; Master 1986; Strayer 1993; U.S. Fish and Wildlife Service 1993; Michaelson and Neves 1995). These four species still occur in the areas of the Petitcodiac watershed that we considered to be suitable habitat for Dwarf Wedgemussel.

One of the former locations of the Dwarf Wedgemussel in the Petitcodiac watershed is no longer suitable habitat for any freshwater mussel species. During the 1984 survey, Clarke and McAlpine did not find Dwarf Wedgemussel in the North River sites from Fawcett to the Route 112 bridge (including the site where it was considered common in 1960) but characterized this stretch of river as being good habitat. In 1997 and 1998, however, this section of river was found to have been severely degraded, principally by poor agricultural practices, and all species of mussels were rare to absent. This habitat degradation included: large areas of black anoxic sediments that gave off methane and

hydrogen sulfide gas when disturbed; sections fenced off across the stream to allow cattle full access to both sides of the river; silting from cattle collapsing the banks and fields cultivated to within 2 or 3 m of the bank; removal of almost all shoreline vegetation adjacent to fields; and ditches and drain-pipes emptying directly into the river. In some places, macrophyte growth was excessive and the plants themselves and the substrate were thickly coated with algae, i.e., conditions under the plants were anoxic. Consequently, it is not surprising that no living mussels were found at these sites.

General Biology

The biology of the Dwarf Wedgemussel has not been studied in Canada. There is limited information on its biology in U.S. waters (e.g., U.S. Fish and Wildlife Service 1993; Michaelson and Neves 1995).

The Dwarf Wedgemussel is a long-term brooder. The eggs are fertilized in mid-summer or autumn, the glochidia mature in the marsupia of females and are released into the water during spring. The glochidium is roughly triangular (0.30×0.25 mm) and has hooks that allow it to attach to the fins or gills of fish, following which it encysts for several weeks before rupturing the cyst and falling to the bottom. The juvenile mussel then buries in soft sediments (sand and fine gravel) where it feeds by filtering algae and fine organic debris from the water. The size- and age-at-first-maturity have not been determined.

Only one study has attempted to determine ages of this species (Michaelson and Neves 1995). It reported frequent shell erosion at the umbo and concluded that ages could not be reliably assigned for most animals showing more than six annuli, although some 10-year-olds were recorded, and the maximum theoretical age was 12 to 18 years. The first attempt to collect Dwarf Wedgemussels after the construction of the Petitcodiac causeway in 1968 was in 1984. The disappearance of the species from the watershed after only 16 years suggests that recruitment failure was almost immediate.

The fish hosts for wild Dwarf Wedgemussels are unknown. Laboratory studies indicate Mottled Sculpin (*Cottus bairdi*), Johnny Darter (*Etheostoma nigrum*), and Tessellated Darter (*E. olmstedii*) can serve as hosts (Michaelson and Neves 1995). Recent (1998) studies have added Pumpkinseed (*Lepomis gibbosus*) and Atlantic Salmon (*Salmo salar*) parr to the list of potential hosts (B. Wicklow, Biology Department, St. Anselm College, Manchester, New Hampshire 03102, personal communication). With the exception of Atlantic Salmon, none of these fish species ever existed in the Petitcodiac watershed. McAlpine (New Brunswick Museum, Saint John; personal communication) and Master (1986) speculated that the loss of the Canadian population of

Dwarf Wedgemussel resulted from the loss of an anadromous fish host following blockage of the Petitcodiac River by the causeway. Although Master (1986) suggested American Eel (*Anguilla rostrata*) as a potential host, this species was not eliminated from the Petitcodiac watershed, and indeed, it was frequently observed during our surveys in 1997–1998.

We think the most likely candidates for a fish host of the Canadian population of Dwarf Wedgemussel were the juvenile freshwater stages of American Shad (*Alosa sapidissima*) or Atlantic Salmon. Fish species which have been eradicated or greatly reduced in occurrence in the watershed by the construction of the Petitcodiac causeway include Atlantic Salmon, American Shad, Striped Bass (*Morone saxatilis*), Atlantic Tomcod (*Microgadus tomcod*), sea-run Brook Trout (*Salvelinus fontinalis*), Rainbow Smelt (*Osmerus mordax*), Alewife (*Alosa pseudoharengus*), and Blueback Herring (*A. aestivalis*). American Shad was the only species known to have occurred at the known Dwarf Wedgemussel collection sites and to have been immediately eliminated from the system. The former spawning and juvenile rearing sites of American Shad correspond closely to the known collection locations of Dwarf Wedgemussel in the Petitcodiac system. However, American Shad has not yet been tested as a potential host in laboratory studies (B. Wicklow, Biology Department, St. Anselm College, Manchester, New Hampshire 03102, personal communication). Atlantic Salmon, which Wicklow has identified as a host in the laboratory, also occur at known collection locations for the Dwarf Wedgemussel, but were more widely distributed than shad in other parts of the watershed. A remnant spawning population of Atlantic Salmon, supplemented by heavy stocking, has persisted. We would have expected some Dwarf Wedgemussels to have been present in 1984 if Atlantic Salmon were a fish host for the glochidial stage, although natural production of juvenile salmon between 1968 and 1979 was low – perhaps too low to support the Dwarf Wedgemussel population. Many of the stocked fish would have gone to sea as smolts within weeks of stocking and would have been unavailable as hosts for the glochidia.

Limiting Factors

All freshwater mussels have two critical early life-history stages: the parasitic (dispersal) stage that usually requires the presence of a specific fish host, and the early post-parasitic stage when specific microhabitat conditions are required for survival (Bauer 1988; Buddensiek 1995; Sparks and Strayer 1998). Although adult freshwater mussels release tens of thousands to millions of glochidia, only a very small fraction of them ever successfully attach to fish and survive to the benthic juvenile stage

(Young and Williams 1983; Jansen and Hanson 1991; Buddensiek 1995). The distribution of freshwater mussel species is determined at this point because if the host fish can not enter a stretch of water, the freshwater mussel species will not be found there (Watters 1992; Graf 1997; Haag and Warren 1998).

Under normal conditions, adult freshwater mussels generally have low natural mortality rates, but their sedentary lifestyle renders them susceptible to a long list of anthropogenic threats. These include: barriers to fish movement, habitat degradation, channelization, over-harvesting, anoxia, metal contamination, and introduction of encrusting competitors (e.g., the Zebra Mussel, *Dreissena polymorpha*) (Nalepa et al. 1991; Bogan 1993; Blalock and Sickel 1996; Ricciardi et al. 1998; Sparks and Strayer 1998). The Dwarf Wedgemussel may be particularly vulnerable to threats because of its typically linear distribution – in most watersheds, the distribution is restricted to an unbranched segment of stream (Strayer et al. 1996). Such linear populations have no spatial refuges from upstream disturbances, unlike populations which occur in numerous branches of a watershed.

Blockage of streams and rivers is one of the most common threats to the persistence of freshwater mussel populations (Bogan 1993; Williams et al. 1993; Layzer et al. 1993; Strayer et al. 1996; Ricciardi et al. 1998) and appears to be the principal cause for the extirpation of the Dwarf Wedgemussel from Canada. The causeway built in the tidal section of the Petitcodiac River in 1967–1968 has had a severe negative effect on populations of anadromous fishes, and, as we speculate above, the loss of an unknown fish host has probably interrupted the life cycle of the Dwarf Wedgemussel. There are numerous examples in the history of the Dwarf Wedgemussel in the USA where its loss from a watershed has been linked with dam construction (U.S. Fish and Wildlife Service 1993).

Other forms of habitat degradation are unlikely to have been factors in the extirpation of the Dwarf Wedgemussel in Canadian waters. Although one section of the North River no longer represents suitable habitat for any species of freshwater mussel, the habitat degradation occurred after the 1984 survey was conducted, at which time the Dwarf Wedgemussel was already absent.

Muskrats (*Ondatra zibethicus*) are the only mammalian predator (other than man) that kills large numbers of adult freshwater mussels (Hanson et al. 1989; Neves and Odom 1989; Jokela and Mutikainen 1995; Tyrell and Hornbach 1998). This predation tends to be localized and does not threaten the existence of populations of endangered freshwater mussels unless an area of high muskrat feeding coincides with a remnant population of an endangered

species (Neves and Odom 1989; Bruenderman and Neves 1993; Hoggarth et al. 1995). It is unlikely that muskrat predation was a factor in the extirpation of the Dwarf Wedgemussel in the Petitcodiac watershed because muskrat predation is not currently widespread in the watershed and tends to focus on mussels of large body size (J. M. Hanson, unpublished data).

Special significance

North America has the highest diversity of freshwater mussels in the world. There are 281 recognized species, of which only 70 are considered to have stable populations, making freshwater mussels the most threatened taxon of its level in North America (Williams et al. 1993; Stein and Chipley 1996; Primack 1998). In many cases, freshwater mussels act as "miner's canaries" for the health of aquatic habitats; their absence indicates a waterbody has been severely degraded.

Clarke (1981b) listed 12 species of freshwater mussel in New Brunswick, one of which, the Dwarf Wedgemussel, is listed as endangered in the USA. Although the species always had a very restricted distribution in Canada, it was one of only two locations where the species was considered to be common (Clarke 1981a) despite being at the extreme northern edge of its range. The other location where Clarke reported the species was common was the Connecticut River system in Vermont. Populations at the edge of the range of a species often contain unique genetic adaptations and, for this reason if for no other, are an important component of biological diversity and are worth protecting (Primack 1998). Whatever unique adaptations allowed the Dwarf Wedgemussel to form a large population in the Petitcodiac River System (Clarke 1981a) were lost with the extirpation of this species from Canadian waters.

Evaluation

The Dwarf Wedgemussel was classified as Extirpated in Canada during the April 1999 meetings of COSEWIC. The disappearance of this species from its known Canadian range corresponds with the construction of the Petitcodiac causeway in 1968, which is believed to have caused local elimination of the unknown host fish species. Since 1984, a portion of the former range of the Dwarf Wedgemussel has been degraded by agricultural runoff, bank destruction by cattle, pesticides and farm chemical dumping, etc. Large stretches of suitable habitat remain in the Little, Petitcodiac, North, and Anagance rivers. Successful re-introduction (from U.S. populations) is unlikely until the native anadromous fish populations (in particular American Shad and Atlantic Salmon) are re-established in the watershed. This would require removal of the blockage caused by the

Petitcodiac causeway. Even with the causeway in place, small numbers of shad and salmon attempt (usually unsuccessfully) to migrate into the river (A. Locke, unpublished data). Part of the former range of the Dwarf Wedgemussel would require substantial rehabilitation to reverse the effects of destructive agricultural practices.

In view of the status of this species in Canada and elsewhere, specimen lots in the museum collections of the New Brunswick Museum, the Nova Scotia Museum, and the Canadian Museum of Nature should have special limitations applied to their use as the collections are irreplaceable.

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The Natural Revegetation of a Vacuum-mined Peatland: Eight Years of Monitoring

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To determine whether a highly disturbed peatland ecosystem was successfully regenerating, we monitored the natural revegetation of a vacuum-mined bog located in southern Québec that was abandoned in 1989 (Cacouna bog). Vegetation surveys were carried out in 1994 and 1998. The presence/absence of all species of vascular and non-vascular plants along eight 264-m long transects was noted in both years. The height structure of the invading birch (*Betula* spp.) population was also reconstructed in 1998. Only 11 plant species were sampled in 1994 at the vacuum-mined site. The 1998 survey added only five other species to the list. Nevertheless, the 1994 and 1998 vegetation surveys were significantly different, particularly because the cover of four ericaceous shrub species (*Chamaedaphne calyculata*, *Kalmia angustifolia*, *Ledum groenlandicum*, *Vaccinium angustifolium*) had increased since 1994. Height structure of the birch population indicated that seedlings were very numerous at the study site, but few of them will probably survive to their first or second growing season. This suggests that the natural revegetation of the Cacouna bog's vacuum-mined (mechanically harvested) site is slowly converging towards that of most block-cut mined (manually harvested) sites in southern Québec; i.e., a dense plant cover dominated by ericaceous shrub species. However, no *Sphagnum* species had established eight years after abandonment of the vacuum-mined section. This indicates that the site is not returning to a functional peatland ecosystem. Additional restoration measures should be elaborated to accelerate the revegetation process.

Pour déterminer si un écosystème tourbeux très perturbé est en voie de régénération, nous avons suivi la recolonisation végétale naturelle d'une tourbière du sud du Québec (Cacouna) où la tourbe a été extraite par aspiration et où toute activité d'extraction a cessé en 1989. Des relevés de végétation ont été effectués en 1994 et 1998. La présence/absence de toutes les espèces de plantes vasculaires et invasculaires a été notée le long de huit transects d'une longueur de 264 m. La structure de taille de la population de bouleaux (espèces envahissantes) a été reconstituée en 1998. Seules 11 espèces de plantes ont été échantillonnées en 1994 dans la section aspirée. Le relevé de 1998 n'a ajouté que cinq espèces supplémentaires à la liste. Néanmoins, les relevés de 1994 et de 1998 sont significativement différents d'un point de vue statistique, particulièrement en raison de la hausse du couvert de quatre éricacées arbustives (*Chamaedaphne calyculata*, *Kalmia angustifolia*, *Ledum groenlandicum*, *Vaccinium angustifolium*) depuis 1994. La structure de taille de la population de bouleaux indique que de nombreux plantules étaient présents sur le site en 1998, mais il est peu probable qu'un grand nombre d'entre eux survivent à leur première ou seconde saison de croissance. Ces données suggèrent que la recolonisation végétale naturelle du site aspiré (récolté de façon mécanique) de la tourbière de Cacouna tend à ressembler de plus en plus à celle de la plupart des sites récoltés de façon artisanale (manuellement) du sud du Québec. On y trouvera donc, à plus ou moins brève échéance, un couvert végétal dense dominé par les éricacées arbustives. Toutefois, aucune espèce de sphaigne n'a encore été en mesure de coloniser le site aspiré huit ans après l'abandon de ce dernier. Le site n'est donc pas en voie de redevenir un écosystème tourbeux fonctionnel. Des mesures additionnelles en matière de restauration devraient être élaborées pour accélérer le processus de recolonisation végétale.

Key Words: Mined peatland, permanent plot, ericaceous shrub, birch, *Betula* spp., Cacouna bog, Québec.

One of the most reliable methods for studying the vegetation dynamic of an ecosystem is through the establishment and long-term monitoring of permanent plots. They are particularly useful for determining the external and internal causes of succession (Bakker et al. 1996), and for evaluating the success of ecosystem restoration programs (Mitsch et al. 1998). Several ecosystems (e.g., forests, grasslands, old fields, salt marshes, sand dunes) have recently been monitored to detect long-term changes in plant species composition and abundance (Bakker et al. 1996). On the other hand, plant communities of ombrotrophic peatlands dominated by *Sphagnum* species have rarely been monitored because succes-

sional changes (e.g., from rich fen to poor fen to bog) are very slow (Kuhry et al. 1993), and natural disturbances (fire) do not seem to change successional pathways because they have low impact on the water table (Kuhry 1994). However, plant succession occurring in peatlands disturbed by peat mining activities (peat extraction for the production of horticultural compost) is often very different from that which occurs at undisturbed sites (Salonen et al. 1992). In general, most bogs that are mined using manual methods (block-cutting of peat) are successfully revegetated by typical-bog species (mainly ericaceous shrubs). The natural revegetation of peatlands mined using tractor-drawn vacuum machines is

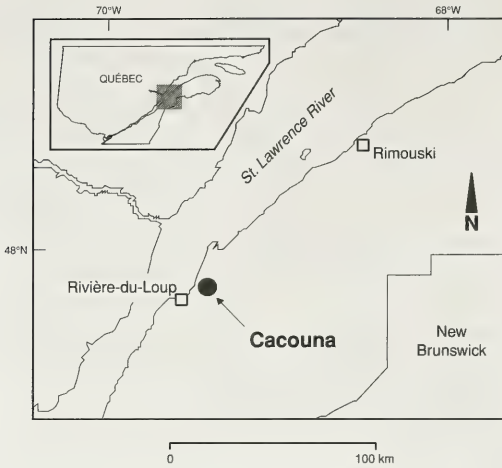


FIGURE 1. Location of the study site (Cacouna bog).

very slow and is dominated by non-bog species such as birches (Lavoie and Rochefort 1996; Lavoie and Saint-Louis 1999; Robert et al. 1999). In eastern Canada, most block-cut bogs have been abandoned for more than 30 years, which is not the case for vacuum-mined peatlands (most sites: ten years maximum). It is possible that revegetation patterns of block-cut and vacuum-mined sites will converge in

the near future and that, on a long-term basis, natural revegetation would be a good alternative to restoration in vacuum-mined bogs, at least for vascular plant species. To test this hypothesis, we sampled, in 1994 and 1998, a vacuum-mined peatland located in southern Québec that was abandoned in 1989. The 1994 survey has been published (Lavoie and Rochefort 1996), and we show here the results of the 1998 survey.

Study Site and Methods

The Cacouna peatland ($47^{\circ}52' \text{ N}$, $69^{\circ}27' \text{ W}$) is located 10 km northeast of the city of Rivière-du-Loup (Figure 1) and 6 km from the south shore of the St. Lawrence River, in Québec (Canada). The altitude of the peatland is 83 m. In 1930, the total area of the bog was 203 ha, but some parts of the peatland have been converted into agricultural lands during the last 70 years. Consequently, in 1995, the total area of the bog was 173 ha. More than 50% of the original surface of the Cacouna peatland (102 ha) was mined (block-cutting of peat) between 1942 and 1975. During this period, more than 34% of the peat volume has been lost due to peat mining and agricultural activities, and also due to peat subsidence. A small section of the bog (16 ha of block-cut peatland) was bulldozed in 1983 to level the peat surface, and to allow an additional peat harvest using tractor-drawn vacuum machines. Additional drainage ditches



FIGURE 2(a). The vacuum-mined section of the Cacouna bog in 1994.



FIGURE 2. The vacuum-mined section of the Cacouna bog in 1998 (top). In 1998, some parts of the vacuum-mined section had a dense cover of ericaceous shrubs (bottom).

TABLE 1. Results of vegetation surveys conducted in the vacuum-mined unit of the Cacouna bog in 1994 and 1998 (*N* sampling points = 536). Data from both surveys were compared for each species using a McNemar's test.

Species	Sampling points (n) for which species ...				\$	
	...was present in 1994 and 1998	...was absent in 1994 and 1998	...was present in 1994 but absent in 1998	...was absent in 1994 but present in 1998	in 1994	in 1998
Trees						
<i>Betula</i> spp.	38	344	73	81	20.7	22.2
<i>Larix laricina</i>	0	533	1	2	0.2	0.4
<i>Picea mariana</i>	0	529	1	6	0.2	1.1
<i>Pinus banksiana</i>	0	535	0	1	-	0.2
Ericaceae (shrub species)						
<i>Chamaedaphne calyculata</i> *	23	391	34	88	10.6	20.7
<i>Kalmia angustifolia</i> *	0	494	5	37	0.9	6.9
<i>Ledum groenlandicum</i> *	9	431	23	73	6.0	15.3
<i>Rhododendron canadense</i>	0	526	3	7	0.6	1.3
<i>Vaccinium angustifolium</i> *	22	379	30	105	9.7	23.7
Other plants						
<i>Dicranella cerviculata</i>	0	532	0	4	-	0.7
<i>Eriophorum vaginatum</i>	3	473	34	26	6.9	5.4
<i>Gaultheria hispidula</i>	0	534	0	2	-	0.4
<i>Nemophanthus mucronata</i>	0	534	0	2	-	0.4
<i>Prunus pennsylvanica</i>	0	534	0	2	-	0.4
<i>Prunus virginiana</i>	0	535	1	0	0.2	-
<i>Rubus chamaemorus</i>	0	522	8	6	1.5	1.1

*Populations (1994, 1998) significantly different for this species ($P < 0.001$).

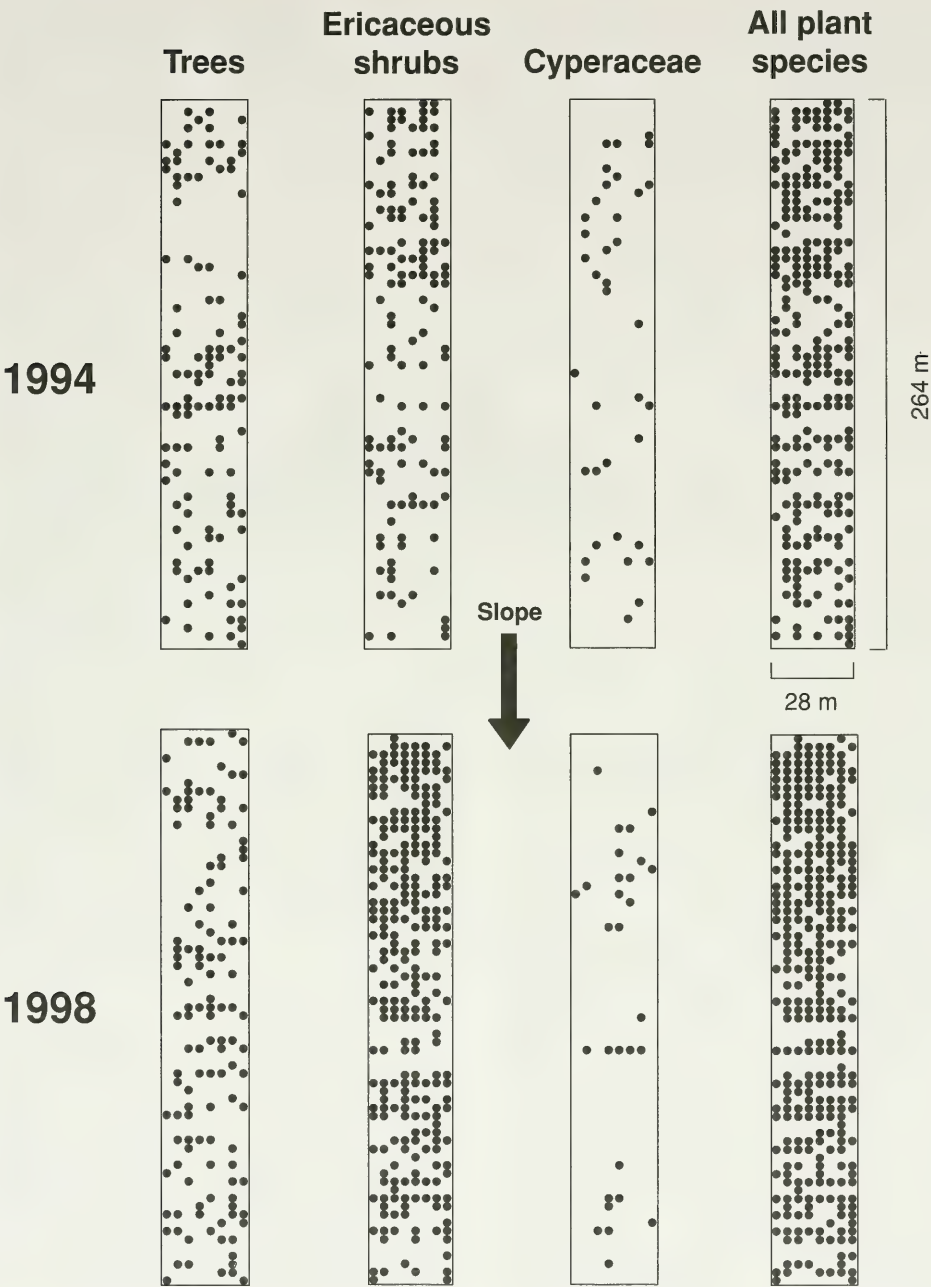


FIGURE 3. Spatial distribution of trees, ericaceous shrubs, cotton grasses (*Eriophorum vaginatum*, Cyperaceae), and of all plant species in the vacuum-mined unit of the Cacouna bog in 1994 and 1998. A taxon covering a sample point (located every 4 m along transects 4 m apart) is represented by a dot.

were dug, separating the bulldozed section into smaller (30 × 270 m) units, and lowering the water table. Peat mining was finally abandoned in 1989, and the remaining peat deposit in the bulldozed sec-

tion was 250-cm thick (M. Girard, C. Lavoie, and M. Thériault, unpublished data).

In August 1994, one of the vacuum-mined units (Figure 2) was randomly selected for vegetation

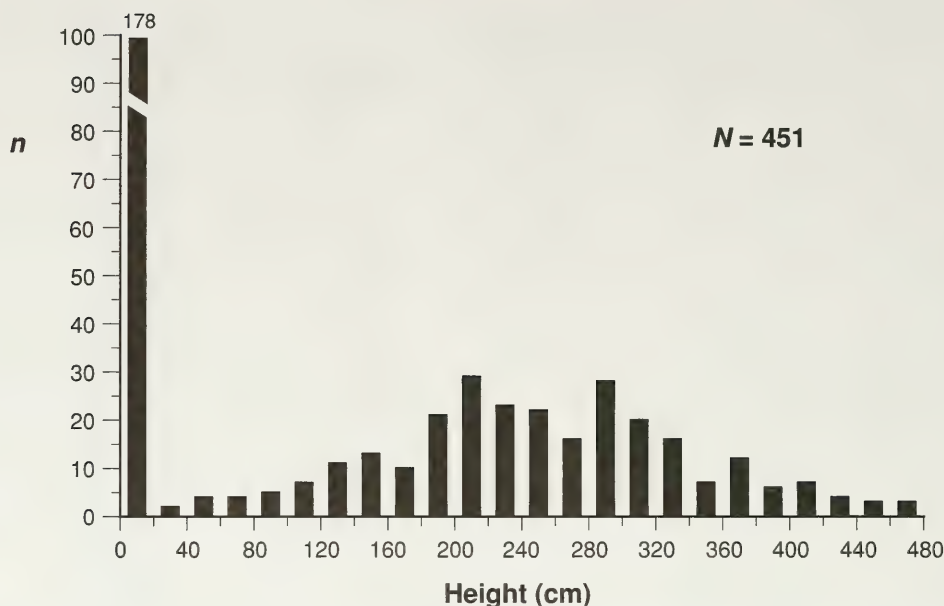


FIGURE 4. Height structure (20-cm classes) of the birch (*Betula* spp.) population of the vacuum-mined unit of the Cacouna bog in 1998.

sampling (Lavoie and Rochefort 1996). The presence/absence of all species of vascular and non-vascular plants covering a small point (diameter: 1 cm) every 4 m along eight transects, 4 m apart and 264 m long, was noted. Furthermore, since the vacuum-mined section has been invaded by birches (*Betula* spp.), 128 birch individuals were randomly selected and a stem section of each individual was taken at the collar. In the laboratory, tree rings were counted on finely sanded cross-sections. Birch species (*Betula cordifolia*, *B. papyrifera*, *B. populifolia*, *B. × caerulea*) were not differentiated because most individuals were hybrids which cannot be easily identified in the field during the summer season (DeHond and Campbell 1989). No exotic birch species (e.g., *Betula pendula*) has been found. In August 1998, the vegetation sampling was repeated at the same place using exactly the same method (Figure 2). The population structure of the birches was constructed by measuring the total height of all stems included in a 25×28 m quadrat located at the center of the vacuum-mined unit. Cross-sections of the stems were not taken so as to minimize disturbance to the tree population.

The 1994 and 1998 surveys were compared using a Wilcoxon's signed-ranks test to verify whether they were significantly different (Scherer 1984). Furthermore, the surveys were compared for each plant species using a McNemar's test to detect whether a species was significantly more or less abundant in 1998 than in 1994. Each sampling point

was then considered to detect if the species was present/absent in 1994 and in 1998 (Scherer 1984). The Bonferroni's correction was applied to weight the significance level ($\alpha = 0.05$) by the number (n) of McNemar's tests used (α/n), i.e., one for each species (Harris 1975).

Nomenclature follows Farrar (1996) for trees, Scoggan (1978-1979) for other vascular plants, and Anderson et al. (1990) for mosses.

Results and Discussion

Only 11 plant species were sampled in 1994 in the vacuum-mined unit. The 1998 survey only added five other species to the list (Table 1), i.e., four vascular plant species (*Gaultheria hispidula*, *Nemopanthes mucronata*, *Pinus banksiana*, *Prunus pensylvanica*), and one moss species (*Dicranella cerviculata*). The dominant species in 1994 (*Betula* spp.) had not significantly increased their cover by 1998. Nevertheless, the 1994 and 1998 vegetation surveys were significantly different ($P < 0.01$), particularly because the cover of four ericaceous shrub species (*Chamaedaphne calyculata*, *Kalmia angustifolia*, *Ledum groenlandicum*, *Vaccinium angustifolium*) had significantly increased since 1994 (Table 1, Figure 2 and 3).

Height structure of the birch population indicated that seedlings (0-19 cm) were very numerous at the study site (Figure 4). However, there are very few individuals in successive height classes (20-180 cm), suggesting that few seedlings will probably survive

to their first or second growing season. Most other birch individuals (64% of those between 20 and 480 cm) had a total height between 180 and 340 cm. These individuals probably established in 1990; i.e., the year following abandonment of the vacuum-mined unit (Lavoie and Rochefort 1996). The low survival rate of birch seedlings is probably associated with the shade created by older birch individuals and by ericaceous shrubs, since birches are shade intolerant. It is unlikely that the high number of seedlings sampled in 1998 resulted from an exceptional seed production in 1997, since early successional birch species are known to produce numerous seeds on a regular basis; i.e., almost every year (Fowells 1965; Houle 1991).

There are two major problems associated with the revegetation by natural processes of most mined bogs. First, the absence of vegetation cover over large surfaces after abandonment of peat mining activities, as well as moisture deficiency in the uppermost peat layer, contribute to erosion of the peat deposit. Wind erosion of the soil surface prevents the successful establishment of seedlings of many bog plant species (D. Campbell, L. Rochefort, and C. Lavoie, unpublished data). In the Cacouna bog, block-cut mined sections were rapidly recolonized by ericaceous shrubs (90% cover) in less than five years (Lavoie and Rochefort 1996). Natural revegetation of the vacuum-mined section by ericaceous shrubs was slower: eight years after abandonment of the site, only 49% of the peat surface was covered by ericaceous shrub species. This difference can be explained by the lower water level in the vacuum-mined section (Lavoie and Rochefort 1996), which is one of the main factors preventing rapid regeneration of mined bogs (M. Girard, C. Lavoie, and M. Thériault, unpublished data). Second, mined sites are prone to biological invasions by non-bog species, and especially by birches (Jonsson-Ninniss and Middleton 1991; Lavoie and Saint-Louis 1999). Birch populations (particularly *Betula populifolia*) are often present in peatlands after fire (Jean and Bouchard 1987; Meilleur et al. 1994). However, only mined bogs are massively invaded by birches. The dense birch population colonizing the Cacouna bog's vacuum-mined site may have a detrimental effect on the water table (Heathwaite 1995), and impede the establishment of other bog species.

Although the Cacouna bog's vacuum-mined site is still hampered by these two problems, the cover of ericaceous shrub species increased between 1994 and 1998 (contributing to soil surface stabilization), and the birch population seems stabilized. This suggests that natural revegetation of the vacuum-mined site is slowly converging towards that of most block-cut mined sites in southern Québec; i.e., a dense plant cover dominated by ericaceous shrub species (Lavoie and Rochefort 1996; Robert et al. 1999).

However, even if natural revegetation of the vacuum-mined section is successful on a long-term basis for vascular plants, it is important to note that no *Sphagnum* species were established eight years after abandonment of the section, mainly because drainage ditches have not been blocked. This is also the case in most block-cut mined sites in the study area. For example, only 10% of the total mined area of the Cacouna bog had a dense *Sphagnum* cover in 1997 (M. Girard, C. Lavoie, and M. Thériault, unpublished data). Since *Sphagnum* species are essential for the formation of a new acrotelm (upper layer of the peat having a live matrix of growing plants), the Cacouna bog as a whole is not returning to a functional peatland ecosystem. Active bog restoration programs, such as blocking drainage ditches and spreading *Sphagnum* diaspores (Price et al. 1998), are thus essential for rapidly re-establishing a moss cover in mined peatlands.

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Nest Density of Shorebirds Inland from the Beaufort Sea Coast, Alaska

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Because scant information exists on the distribution, abundance, and habitat use of shorebirds nesting in the National Petroleum Reserve-Alaska, we determined nest densities of shorebirds in tundra habitats at Inigok, Alaska. We searched for shorebird nests on 29 plots (4 ha each) between 10 June and 18 July 1998 and surveyed for plover pairs on a 12.8-km² plot. Thirteen shorebird species bred at Inigok, and nest density was highest in drained-lake basins (mean = 80.0 nests/km²). Semipalmated Sandpipers (*Calidris pusilla*) and Pectoral Sandpipers (*C. melanotos*) were the most abundant shorebirds breeding at Inigok and nested exclusively in drained-lake basins (mean = 30.0 nests/km² each). Only American Golden-Plovers (*Pluvialis dominica*) nested in appreciable numbers (2.57 pairs/km² on a single plot) in tussock/ridge tundra. Although constituting a relatively small proportion of the tundra at Inigok (10.5%), drained-lake basins supported a disproportionate number of breeding species and individuals and may support sizable portions of the populations of Semipalmated Sandpipers and Pectoral Sandpipers breeding on the North Slope. Development plans for inland sites on the North Slope should consider the importance of drained-lake basins to nesting shorebirds.

Key Words: *Calidris*, Sandpipers, shorebirds, density, nest, tundra, breeding, Alaska.

On Alaska's North Slope, an area that extends north from the Brooks Range to the Arctic Ocean, the National Petroleum Reserve-Alaska (NPR-A) provides some of the most productive shorebird habitat in northern Alaska. Thirty-one species of shorebirds are known to have bred on the North Slope and nearly 6 million shorebirds are thought to spend the summer in the 95 800 km² NPR-A (Pitelka 1974; Gusey 1979*). Despite the high diversity of breeding shorebirds, little quantitative information exists on their distribution and abundance among tundra habitats in NPR-A.

Our knowledge of North Slope shorebirds has come mainly from multiple-year studies in a few locations that include recent work at Prudhoe Bay (e.g., Troy 1996) and the Colville River Delta (Andres 1994; J. R. Bart, U.S. Geological Survey, personal communication) and earlier studies in the Arctic National Wildlife Refuge (Martin 1983; Oates et al. 1985*) and at Barrow (e.g., Myers and Pitelka 1980*). Most studies were restricted to coastal areas within the Arctic Coastal Plain province (Wahrhaftig 1965), whereas work inland from the coast in the Arctic Foothills and Arctic Mountains provinces has been largely neglected. Furthermore, few data on shorebird nest densities are available for the NPR-A; previous investigators combined counts of individuals during breeding and nonbreeding seasons, did not

sample all habitats shorebirds used, did not design studies to yield estimates of nest density, or focused on coastal-zone use during migration (e.g., Connors et al. 1984*; Derksen et al. 1981; King 1979*; Myers and Pitelka 1980*). Lastly, much of the information on nest densities and habitat use of shorebirds on the North Slope exists only in unpublished sources.

Because of increasing oil development pressure within the NPR-A (U. S. Department of the Interior 1998*), habitats that support high densities of nesting shorebirds need to be identified. Information currently available is inadequate to assess the importance of regions or habitats to shorebirds breeding there. We therefore initiated a field study at Inigok, a site located inland from the Beaufort Sea coast, to determine nest densities of shorebirds in tundra habitats.

Study Area

Inigok is located 65 km from the Beaufort Sea (70°00' N, 153°05' W; Figure 1) and is dominated by tussock tundra with relatively high relief (elevations ranged from 30 to 80 m). The area has numerous large lakes and ponds that lie in an ancient dune complex oriented in an east-west direction. Lakes are often bordered on the east and west by drained-lake basins (former lakes that have gradually drained over time) and on north and south by bluffs (5–10 m). Patterned ground (polygons) is rare in the area but is sometimes associated with drained-lake basins and former stream channels. Tapped lakes (lake basins

*See Documents Cited section.



Figure 1. Location of shorebird nesting study at Inigok on the North Slope of Alaska, 1998.

that are breached by a stream and have rapid drainage) and beaded streams (streams interrupted by numerous pools) feed the Fish and Inigok creek drainages. A gravel airstrip constructed in 1978 to support the drilling of an oil exploration well provided access to the site.

Methods

We used a vegetation classification map of the NPR-A generated by the Bureau of Land Management and Ducks Unlimited (BLM/DU; Kempka et al. 1995*) to define three major vegetation cover types at Inigok: drained-lake basin, tussock tundra, and ridge tundra. Drained-lake basins comprised a mosaic of aquatic, wet, and moist tundra and were usually associated with large lakes. Tussock tundra dominated gradual slopes and consisted of moist to dry sedge and prostrate shrubs. This was the most common vegetation type at Inigok and it formed a transition between drained-lake basins and ridge tundra. Ridge tundra occurred in narrow bands of hummocky, disturbed soil colonized by *Dryas* spp., *Cassiope* spp., and lichens.

To compare shorebird nest densities among inland sites on the North Slope, we collapsed the habitat classification scheme used on the Arctic National Wildlife Refuge (ANWR) by Oates et al. (1985*) into two major vegetation types — upland and lowland tundra. Four of their vegetation types (flooded, wet sedge, moist sedge, and mosaic tundra), derived from Walker et al. (1982), constituted lowland tundra cover types that were similar to drained-lake basins at Inigok. Upland tundra comprised moist sedge-shrub and tussock classes of Oates et al.

(1985*) and was similar to combined tussock/ridge tundra at Inigok.

We delineated 29 survey plots within 7 km of camp; random plot locations were selected by GIS-based stratification of vegetation types. Within each of the three tundra vegetation types, we placed several 4-ha plots for intensive nest searching. Dimensions of drained-lake basin and tussock plots were 200 m \times 200 m, and dimensions of ridge plots were 400 m \times 100 m (designed to more closely follow natural delineations of ridge habitat). Plot-corner (tussock and basin plots) or center-line (ridge plots) locations were determined by PLGR-GPS (Precision Lightweight Ground Receiver — Global Positioning System), and all plots were delineated on the BLM/DU vegetation map. Boundaries were marked with wire flags to aid navigation on the plot. Ten plots (40 ha total) each were placed in drained-lake basin and tussock tundra, and nine plots were placed in ridge tundra (36 ha total).

Between 10 June and 8 July 1998, we searched plots at 7- to 10-day intervals to locate all shorebird nests. Intensive nest searching was performed by a single observer who walked the plot in a "zig-zag" manner in an attempt to record all nests within plot boundaries; rope-dragging was not performed. Duration of plot surveys varied from 1 to 6 hours and depended on nest density, bird abundance, and plot vegetation type; drained-lake basin plots required the most time, and ridge plots required the least. Besides finding nests, observers recorded the number, species, and sex (when possible) of all shorebirds present during each plot visit. To minimize bias due to differences in nest-finding ability, we rotated

assignments to avoid sequential searches of a plot by the same observer.

We used a two-sample randomization procedure to compare species-specific nest density among the tussock/ridge tundra and drained-lake basins (Manly 1991). We performed 5000 iterations for each test to compute a mean difference between habitats (*D*) and associated *P*-values. Standard errors of mean nest density, using normal equations, were calculated for each cover type. We used the relative distribution of tussock/ridge tundra and drained-lake basins, computer-derived from the BLM/DU map, to define stratum weights and used a stratified random sample estimator to determine the mean nest density for the entire Inigok area.

In addition to intensive plot surveys, we searched for American Golden-Plover (*Pluvialis dominica*) and Black-bellied Plover (*P. squatarola*) pairs on a 12.8-km² plot, within the study area boundaries, during a single, intensive nest-searching period (20 – 23 June). For each plover pair found, we attempted to locate a nest to confirm breeding; all pair and nest locations were plotted on 1:63 000 aerial photos. Plover surveys were made across all vegetation types and yielded an absolute density of nesting plovers at Inigok (we did not include lakes, ponds, the airstrip, or other disturbed areas in our calculation of plover density).

Results

Thirteen shorebird species bred at Inigok in 1998. Ten of these nested on our 4-ha plots (Table 1), and one additional species, the Black-bellied Plover, nested on the plover study area. The Western Sandpiper (*Calidris mauri*) and Ruddy Turnstone (*Arenaria interpres*) nested in low densities at Inigok but were not recorded on plots. Although shorebirds nested in all vegetation types sampled on 4-ha plots, the density of all species was highest in drained-lake basins and was significantly higher there than in tussock/ridge tundra (randomization test, *D* = 68.2, *P* = 0.0002). Semipalmated Sandpipers (*C. pusilla*) and

Pectoral Sandpipers (*C. melanotos*) were the most abundant shorebirds nesting at Inigok, and both nested exclusively in drained-lake basins (Table 1). Thus, nest densities of these two species were significantly higher in drained-lake basins than in tussock/ridge tundra (*D* = 30.0, *P* = 0.0002). Nest density of Red-necked Phalaropes (*Phalaropus lobatus*) tended to be higher in drained-lake basins than in upland tundra (*D* = 10.0, *P* = 0.0568). Too few nests of other shorebird species were found to detect significant, species-specific differences in density between tundra vegetation types (Table 1).

We found 20 American Golden-Plover nests (1.56 nests/km²) of 33 probable breeding pairs (2.57 pairs/km²) within the plover study area but only three pairs (0.23 pairs/km²) and two nests (0.16 nests/km²) of Black-bellied Plovers. Most nests of American Golden-Plovers were found in ridge tundra or on sparsely vegetated hummocks in tussock tundra, whereas nests of Black-bellied Plovers were located on sparsely vegetated hummocks in drained-lake basins or in a similar vegetation type found in abandoned creek channels.

Discussion

Our study at Inigok is only the second in the NPR-A to furnish nest densities of shorebirds breeding inland from the Beaufort Sea coast. The other site, Atkasook (located 48 km from the coast), was surveyed for three years in the late 1970s (Myers et al. 1978, 1979, 1980), and the lowland habitats sampled there closely corresponded to drained-lake basins at Inigok. Although nest density of all shorebirds in drained-lake basins at Inigok exceeded that found in lowland tundra at Atkasook (48.3 nests/km²), nest density across the entire Inigok area was about 50% lower.

Overall nest density at Inigok was also lower than at coastal locations on the North Slope. Mean density (nine years) on randomly selected plots at Pt. McIntyre, Alaska, was 39.8 nests/km² (Troy 1996); nest density of Semipalmated Sandpipers there (12.6

TABLE 1. Mean nest densities (nests/km²) and (± standard errors) of shorebirds found in tussock/ridge tundra and drained-lake basin vegetation types at Inigok, Alaska, in 1998.

Species	Tussock/ridge tundra (n = 19)	Drained-lake basin (n = 10)	Study area (n = 29)
American Golden-Plover	5.26 ± 2.40		4.52 ± 2.06
Bar-tailed Godwit (<i>Limosa lapponica</i>)		2.50 ± 2.50	0.36 ± 0.36
Semipalmated Sandpiper		30.0 ± 8.2	4.26 ± 1.16
Pectoral Sandpiper		30.0 ± 6.2	4.26 ± 0.89
Dunlin (<i>Calidris alpina</i>)	1.32 ± 1.32		1.13 ± 1.13
Silt Sandpiper (<i>Calidris himatopus</i>)	1.32 ± 1.32	2.50 ± 2.50	1.48 ± 1.18
Buff-breasted Sandpiper (<i>Tryngites subruficollis</i>)	1.32 ± 1.32		1.13 ± 1.13
Long-billed Dowitcher (<i>Limnodromus scolopaceus</i>)	2.63 ± 2.63	5.00 ± 5.00	2.97 ± 2.37
Red-necked Phalarope		10.0 ± 7.6	1.42 ± 1.08
All species	11.8 ± 4.0	80.0 ± 13.8	21.3 ± 3.9

nests/km²) was three times higher than overall nest density of this sandpiper at Inigok. Similarly, mean nest density of Semipalmated Sandpipers on randomly selected plots on the Canning River Delta, a coastal site in the ANWR, was 15.7 nests/km² (Martin 1983). Pair density of American Golden-Plovers, the only common shorebird breeding in tussock/ridge tundra, was similar to nest density recorded at Atkasook (Myers et al. 1978, 1979, 1980) and Pt. McIntyre (Troy 1996). Compared to a coastal site, Jones et al. (1980) also found reduced densities of shorebirds on a 100-ha plot 70 km inland along the Sagavanirktok River. Breeding shorebird richness at all inland sites, however, was as high, if not higher, than at coastal sites of a corresponding longitude. The number of shorebirds breeding at Inigok in a single year represented 87% of all species breeding 110 km to the northeast on the Colville River Delta over a 10-year period (Jonathan Bart, U.S. Geological Survey, personal communication).

Nest densities of all shorebirds varied almost eight-fold between drained-lake basins and tussock/ridge tundra at Inigok. Semipalmated Sandpipers, Pectoral Sandpipers, and Red-necked Phalaropes nested exclusively in drained-lake basins. The concentration of Red-necked Phalaropes in drained-lake basins is consistent with their use of lowland tundra at other sites on the North Slope (Oates et al. 1985*). The disparity in nest density of Pectoral and Semipalmated Sandpipers between tussock/ridge tundra and drained-lake basins at Inigok differed from more equitable nest densities between upland and lowland tundra found in the ANWR (Oates et al. 1985*; Table 2). The difference in habitat use between ANWR and Inigok may reflect variation in topographic features of their respective landscapes and, to a lesser extent, the vegetation classification used in each study. The study area at

Inigok was characterized by higher elevations and had steeper hydrological gradients from uplands to lowlands than did sites in the ANWR. Poor drainage in upland tundra in the ANWR resulted in a mosaic of moist and dry habitat patches that was suitable for nesting by Semipalmated Sandpipers and Pectoral Sandpipers (Oates et al. 1985*). Higher density and numbers of breeding shorebirds recorded at Atkasook, relative to coastal Barrow, were also attributed to the juxtaposition of upland and lowland tundra (Myers et al. 1978). Nest selection in many calidrine sandpipers is likely based on food availability and proximity to feeding areas, such as ponds, lakes, and wet tundra, where aquatic and semi-aquatic insects are abundant (Holmes and Pitelka 1968). At Inigok, moist foraging areas were restricted to drained-lake basins; consequently, nesting shorebird densities there were high.

The densities of shorebirds nesting in drained-lake basins at Inigok were some of the highest recorded on the North Slope. Nest densities of Pectoral Sandpipers can vary considerably among years (Oates et al. 1985*; Troy 1996). However, nest density of Pectoral Sandpipers in drained-lake basins at Inigok was only exceeded in a single year at Pt. McIntyre (33 nests/km² on random coastal plots; Troy 1996), the Jago Delta (40 nests/km² on plots in moist sedge; Oates et al. 1985*), and Niguanak (33 nests/km² on plots in moist sedge-shrub; Oates et al. 1985*). No site surveyed on the North Slope had a higher nest density of Semipalmated Sandpipers than drained-lake basins at Inigok. Annual variation in nest density of Semipalmated Sandpipers and of most other shorebird species is much less than for Pectoral Sandpipers (Oates et al. 1985*; Troy 1996). Although nest densities of Pectoral Sandpipers based on a single-year study at Inigok should be viewed cautiously, relative use among tundra vegetation

TABLE 2. Nest density (nests/km²) of shorebirds at inland sites on the National Petroleum Reserve — Alaska (Atkasook) and Arctic National Wildlife Refuge (Niguanak, Jago Bitty, Aichilik), North Slope, Alaska.

Species	Lowland tundra				Upland tundra		
	Atkasook ¹	Niguanak ²	Jago Bitty ³	Aichilik ⁴	Niguanak	Jago Bitty	Aichilik
Black-bellied Plover	2.68						
American Golden-Plover	1.32	5.00	1.67	4.15	0.84	3.33	5.84
Semipalmated Sandpiper	21.3	1.67				6.67	1.67
Pectoral Sandpiper	8.00	11.7	10.9	3.35	17.5	5.00	10.9
Dunlin	6.68	1.67					
Stilt Sandpiper		1.67	3.33	0.84			
Buff-breasted Sandpiper			0.84				
Long-billed Dowitcher		1.67					
Red-necked Phalarope	2.68	8.33	0.84		1.67		0.84
Red Phalarope (<i>Phalaropus fulicaria</i>)	5.60	1.67					

¹48 km inland from the coast, surveyed 3 yr, primarily includes lowland tundra types (Myers et al. 1978, 1979, 1980).

²240 km inland from the coast, surveyed 1 yr (Oates et al. 1985*).

³40 km inland from the coast, surveyed 2 yr (Oates et al. 1985*).

⁴35 km inland from the coast, surveyed 2 yr (Oates et al. 1985*).

types of this and other species should be representative of similar inland sites; habitat use patterns of post-breeding shorebirds were invariant between years on the Colville River delta (Andres 1994).

Although drained-lake basins constitute a relatively small proportion of shorebird habitat at Inigok (10.5%), they support a disproportionate number of breeding species and individuals. The large disparity between densities in drained-lake basins and tussock/ridge tundra indicate that little suitable nesting habitat exists outside of basins. If Semipalmated Sandpiper and Pectoral Sandpiper nest densities at Inigok are typical, inland drained-lake basins may provide habitat for a sizable portion of their North Slope breeding populations. Because of earlier snow melt, inland drained-lake basins may provide alternative breeding sites in years of late snow melt or cold temperatures on the coast. Clearly, oil development plans on the North Slope inland from the Beaufort Sea coast should consider the importance of drained-lake basins to breeding shorebirds and avoid these areas.

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Undetected Eggs: A Waterfowl Nest Box Survey Problem?

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I assessed rates at which unhatched Wood Duck (*Aix sponsa*), Hooded Merganser (*Lophodytes cucullatus*), and Common Goldeneye (*Bucephala clangula*) eggs broke in and/or disappeared from nest boxes over winter. Eggs of different species remained intact at significantly different rates ($P < 0.001$). Evidence from unhatched Hooded Merganser eggs appeared to be most detectable (92–97%), followed by those of Wood Ducks (77–89%), and Common Goldeneyes (53–92%). These species are sometimes sympatric, and differential detection of unhatched eggs in winter nest box surveys could cause species differences in the proportion of nesting attempts detected as well as a differential positive bias in estimates of production from known nests.

Key Words: Wood Ducks, *Aix sponsa*, Hooded Mergansers, *Lophodytes cucullatus*, Common Goldeneyes, *Bucephala clangula*, cavity nesting waterfowl, nest box surveys, undetected eggs, Minnesota.

Monitoring waterfowl nest boxes to document use and nesting success can furnish information regarding population trends as well as annual productivity (Kelley 1997; Zicus and Hennes 1987). Nest box checks also can provide insight on relative species abundance where more than one cavity nesting species occurs (Zicus and Hennes 1988). Although repeated surveys conducted during the nesting season will provide the most accurate assessment of duckling production from nest boxes (Utsey and Hepp 1997), often single surveys are conducted after the nesting season (Bellrose and Holm 1994). In northern regions these may be timed to take advantage of easier access in late winter, and thus may occur as long as several months after the nesting season.

Problems associated with single post-season surveys likely vary with location. Utsey and Hepp (1997) recently reported that single nest box inspections immediately after the season underestimated the number of Wood Duck (*Aix sponsa*) eggs laid and ducklings produced by a factor of 2.5, largely because of undetected multiple nesting. Wood Ducks have long nesting seasons in the southern United States, and multiple nesting and double brooding in a single nest box can be common (Fredrickson and Hansen 1983; Utsey and Hepp 1997). Other concerns may be important where different species of cavity nesting waterfowl are sympatric. In Minnesota, for example, nesting seasons are short, but up to four species sometimes nest in boxes (Zicus and Hennes 1988). Zicus and Hennes (1987) concluded that trained observers conducting winter nest-box checks correctly identified species 91–95% of the time. However, even though there was no multiple nesting, approximately 13% of nests were undetected in late winter, presumably because of loss of evidence.

A better understanding of temporal, regional, and species-related variability in the detection of nesting evidence is needed for nest-box data collected after the nesting season to have the most value. The eggs of different cavity-nesting waterfowl vary in both size and eggshell thickness (Bent 1923, 1925). Thus, there is reason to question whether unhatched eggs survive equally over time for all species and how this might affect production estimates made from nest-box surveys. I compared the rates that unhatched eggs from different species of waterfowl remained intact in nest boxes over winter. Although nondetection of unhatched eggs might cause a small fraction of nesting attempts to be overlooked in post-season surveys, I focused primarily on the consequences of uncounched unhatched eggs in known nests. Specifically, I used estimates of nondetection to assess the potential bias in duckling production estimated from known nests using data typically collected in post-season surveys.

Study Area and Methods

The study was conducted using wooden nest boxes located in northcentral Minnesota. Boxes were located around a 16-ha pond having an adjoining 30-ha sedge meadow and floating mat. Surrounding uplands were approximately 80–85% forested by mixed stands of Trembling Aspen (*Populus tremuloides*), Paper Birch (*Betula papyrifera*), and three species of pine (*Pinus* spp.). Potential mammalian nest predators/scavengers included Raccoons (*Procyon lotor*), Fishers (*Martes pennanti*), Red Squirrels (*Tamiasciurus hudsonicus*), Gray Squirrels (*Sciurus carolinensis*), and several microtine species common to northcentral Minnesota. Potential avian nest predators/scavengers included Blue Jays (*Cyanocitta cristata*), Common Grackles (*Quiscalus*

quiscula), Northern Flickers (*Colaptes auratus*), and possibly other woodpeckers.

In summer of 1982 and 1983, I collected unhatched eggs from successful Wood Duck, Common Goldeneye (*Bucephala clangula*), and Hooded Merganser (*Lophodytes cucullatus*) nests being monitored for other studies. Although Common Mergansers (*Mergus merganser*) also use nest boxes in Minnesota, their eggs were not sufficiently numerous to be used in the study. Three eggs from each species were put into each of a sample of nest boxes in late June. Boxes were revisited in mid-March the following year to determine presence of eggs. When eggs were present, their condition was rated as intact or cracked/broken.

Differences among species and between years in the proportion of intact eggs remaining were tested for with a linear mixed model using SAS PROC MIXED (Littell et al. 1996). Individual nest boxes were modeled as blocks to account for effects attributable to box location and orientation. Variances were stabilized using the angular transformation on the proportion of unbroken eggs of each species remaining in each nest box. The model including species and year was used when the interaction between species and year was not significant ($\alpha = 0.05$). Simultaneous pairwise contrasts between species were made using the LSMEANS statement.

Estimates of minimum and maximum egg detection rates were made by assuming that only intact eggs, and both intact as well as broken eggs, respectively, would be detected. I examined how nondetection of unhatched eggs in known nests might affect the ratio of estimated to actual production when production was estimated by subtracting the number of unhatched eggs from the clutch size. This was modeled by simultaneously considering the egg detection rate and hatching success (i.e., the proportion of eggs hatching in successful nests). The joint function determining the ratio of estimated to actual production was defined as follows:

let k = number eggs in the population of successful nests,
 S = hatching success,
 R = detection rate of unhatched eggs, and

C = ratio of estimated hatched eggs to actual hatched eggs.

Then, kS = actual number of hatched eggs,
 $(k - kS)R$ = number of unhatched eggs that are detected, and
 $k - (k - kS)R$ = estimated number of hatched eggs.

Thus, $C = (k - (k - kS)R)/kS$,
or $C = (1 - (1 - S)R)/S$.

Results

Eggs were placed in 14 nest boxes in 1982 and in 11 of these boxes in 1983 (Table 1). There was no species by year interaction influencing the proportion of eggs found intact in March ($F_{2,56} = 0.7$, $P = 0.5$). Likewise, year did not affect the proportion of intact eggs ($F_{1,58} = 0.25$, $P = 0.62$). In contrast, the species effect was highly significant ($F_{2,58} = 16.5$, $P < 0.001$). Multiple comparison tests indicated that the probabilities of eggs remaining intact differed for all species (Wood Duck vs. Common Goldeneye $P = 0.001$; Wood Duck vs. Hooded Merganser $P = 0.022$; Common Goldeneye vs. Hooded Merganser $P < 0.001$).

Considering both minimum and maximum detection rates, Hooded Merganser eggs had the highest detection (92-97%), followed by those of Wood Ducks (77-89%), and Common Goldeneyes (53-92%). Bias in nest box productivity estimates (i.e., the ratio of estimated production from a population of nest boxes to the actual production) depends on both the detection rate and the hatching success (Figure 1). Bias begins to accrue when both rates are < 1.0 , and increases as either rate decreases further. If detection rate and hatching success were both as low as 0.5, estimated production from known nests would be 1.5 times actual production.

Discussion

Over-winter survival of an egg in a nest box is likely a function of both shell thickness and egg size. Eggs with the thinnest shells might be expected to be the most fragile for any number of reasons, and small eggs might be more easily removed by scavengers than larger ones. Hooded Merganser

TABLE 1. Overwinter status of 225 cavity nesting waterfowl eggs placed in nest boxes in June and reexamined in March, 1982-1984.^a

Species	1982-1983						1983-1984					
	Intact		Broken		Gone		Intact		Broken		Gone	
	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
Wood Duck	34	(81.0)	5	(11.9)	3	(7.1)	24	(72.7)	4	(12.1)	5	(15.2)
Common Goldeneye	21	(50.0)	17	(40.5)	4	(9.5)	19	(57.6)	12	(36.3)	2	(6.1)
Hooded Merganser	40	(95.2)	1	(2.4)	1	(2.4)	29	(87.9)	3	(9.1)	1	(3.0)

^aThree unhatched eggs from each species were placed in each of 14 and 11 nest boxes in June 1982 and 1983, respectively.

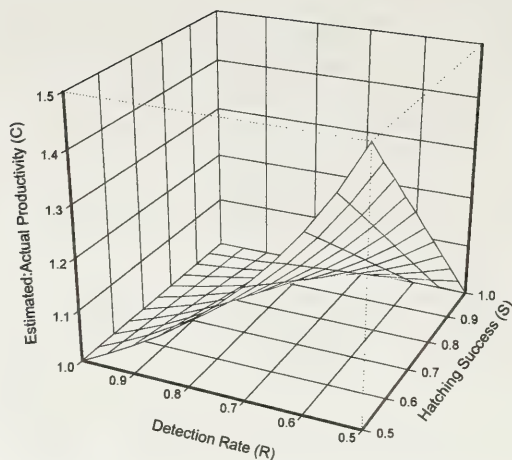


FIGURE 1. Ratio of estimated to actual production (C) as determined by the detection rate (R) of unhatched eggs and the hatching success (S) of eggs in successful nests.

eggshells are approximately 1.5 times as thick as those of Common Goldeneyes and twice as thick as those of Wood Ducks (Dugger et al. 1994; Soulliere 1987; Zicus et al. 1988), so it was not surprising that a higher proportion of their eggs survived over winter than did those of the other two species. In contrast, Common Goldeneye eggshells, although thinner than Hooded Merganser's, are 35-40% thicker than Wood Duck eggshells. Thus, one might not expect Common Goldeneye eggs to be the most fragile. Zicus et al. (1988) measured goldeneye eggshells that were 15% thinner than museum eggs collected about 1900 and determined that 21% of the shell weight variation, controlled for egg size, was explained by DDE concentrations. Furthermore, 8.5% of the Common Goldeneye eggs they observed in successful nests cracked or broke during incubation compared to only 1% of the Wood Duck or Hooded Merganser eggs. Perhaps shell thinning has weakened Common Goldeneye eggshells and contributed to their high rate of over-winter breakage.

I did not test for species differences in rates of egg disappearance because relatively few eggs disappeared completely. Wood Ducks have the smallest eggs of the three species studied (Bellrose and Holm 1994; Dugger et al. 1994; Eadie et al. 1995), and the data suggested that their eggs might have disappeared at the highest rate. Common Goldeneye eggs, although being the largest of the three species, seemed to disappear at a rate nearly equal to Wood Ducks. Perhaps, disappearance of goldeneye eggs might have been facilitated by their greater tendency to break. Hooded Merganser eggs seemed least likely to disappear over winter. Broken eggs that had not been removed sometimes were so severely fractured

that distinguishing their remains from those of hatched eggs would have been difficult had the box actually contained remnants of a hatched nest. Consequently, detection rates for unhatched eggs in an actual survey likely would have been between the estimated maximum and minimum.

Unhatched eggs represent only one type of useful nesting evidence. In an actual survey, production estimates will be affected differently depending on the level and type of undetected nesting evidence. Studies (Utsey and Hepp 1997; Zicus and Hennes 1987) have determined that some nesting attempts are missed completely in post-nesting-season box surveys, particularly where multiple broods are common. Consequently, production estimates are biased negatively, and the bias can be considerable (Utsey and Hepp 1997). Uncounted hatched eggs also result in a negative bias but probably to a lesser degree than do undetected nests. Hatched eggs can go uncounted because detected eggshell membranes indicative of hatched eggs (Girard 1939) are often fewer than the number of young (e.g., Stephens et al. 1998: 162). Membranes become increasingly difficult to detect as the elapsed time since hatching increases (personal observation). In contrast, when production is estimated by subtracting the number of unhatched eggs from a known or assumed clutch size, uncounted unhatched eggs will result in a positive bias.

The amount of bias in production estimates from known nests due to nondetection of unhatched eggs likely will be variable because the resulting bias depends jointly on the proportion of eggs hatching in successful nests and the detection rate for unhatched eggs. Hatching success varies widely in cavity-nesting waterfowl depending, at least in part, on the prevalence of intraspecific nest parasitism. For example, hatching success as low as 50% has been reported for parasitized Wood Duck nests (Bellrose and Holm 1994: 244). This value, in conjunction with the maximum and minimum detection rates for unhatched Wood Duck eggs that I measured, would result in duckling production from known nests being overestimated by 11 to 23%. In contrast, hatching success for Hooded Mergansers has been reported to be as high as 94.7% (Zicus 1990). This value and the maximum and minimum rates of egg detection reported here would result in estimated merganser production having little bias (0.2 to 0.4%). Post-season surveys of waterfowl nest boxes may be the least costly in some locations, but biologists must appreciate their various shortcomings, particularly when comparing among species or locations.

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A Helicopter-based Survey of Waterfowl Broods in Central Ontario

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The Precambrian shield region of central Ontario supports numerous breeding waterfowl, but only localized attempts to document brood production have been undertaken. During summers of 1990 and 1991, we conducted brood surveys, via helicopter, on 13 100-km² (10 km × 10 km) survey plots. The most common broods were Mallard, Black Duck, Wood Duck, Hooded Merganser, and Ring-necked Duck. Observations of these species were in proportion to, or greater than, expected frequencies compared to abundance of breeding pairs. Class IIb–III brood sizes for all species were similar to those reported from ground surveys in other areas of eastern Canada and the United States. Peak hatching for all species occurred from 1 June to 15 July. Based on numbers of breeding waterfowl and the general agreement between brood and pair ratios, considerable waterfowl production likely occurs in central Ontario. We suggest that brood surveys in central Ontario start no earlier than 25 June and end by 25 July. Surveys are expensive, so effort should be stratified based on breeding pair densities. For cost-effectiveness, a single survey in late July may provide a reliable production index for both early and late-nesting species.

Key Words: Mallard, *Anas platyrhynchos*, Black Duck, *Anas rubripes*, Wood Duck, *Aix sponsa*, Hooded Merganser, *Lophodytes cucullatus*, Ring-necked Duck, *Aythya collaris*, helicopter, waterfowl, broods, survey, Ontario.

Forested regions of Canada support an abundant and diverse assemblage of breeding waterfowl (Bellrose 1980). Specifically, the Precambrian shield region of central Ontario supports, on average, >100 indicated waterfowl pairs per 100-km² (Ross 1987). In some areas, densities of Wood Duck (*Aix sponsa*), Mallard (*Anas platyrhynchos*), Hooded Merganser (*Lophodytes cucullatus*), Black Duck (*Anas rubripes*), and Ring-necked Duck (*Aythya collaris*) exceed 90, 60, 40, 30, and 30 indicated pairs per 100-km², respectively (Ross and Fillman 1990). Although waterfowl breeding in forested regions of eastern Canada may contribute significantly to annual fall flights (Ross 1987; Strange et al. 1989), only localized attempts to document brood production have been made in Ontario (Young 1968; McNicol et al. 1987: 43). Knowledge of brood production over large geographic areas is necessary to assess production and to identify waterfowl management needs in eastern breeding areas.

The relative inaccessibility and remoteness of central Ontario dictate the need for aerial-based surveys (Ross 1985). Breeding waterfowl have been surveyed via helicopter since 1981 in central Ontario (Ross 1985; Ross and Fillman 1990), but brood surveys have not been conducted. We present results of a helicopter-based brood survey in central Ontario and discuss the potential for using helicopters to survey waterfowl broods in forested regions of eastern Canada and the northeastern United States.

Methods

The 63 000-km² study area was located in central Ontario (Figure 1). On average, small wetlands

(<9.9 ha) occur at densities of approximately 50 wetlands per 100-km², and represent nearly 80% of the available wetland habitat (McNicol et al. 1987: 16–21). Northern and western portions of the study area are hilly and are dominated by coniferous forest, whereas southern and eastern portions are relatively flat and dominated by mixed forest (McNicol et al. 1987: 16–21).

We conducted waterfowl brood surveys on 13 100-km² (10 km × 10 km) plots (Figure 1) that are annually surveyed by the Canadian Wildlife Service (Ross and Fillman 1990) to monitor numbers of breeding waterfowl in central Ontario (part of the Black Duck

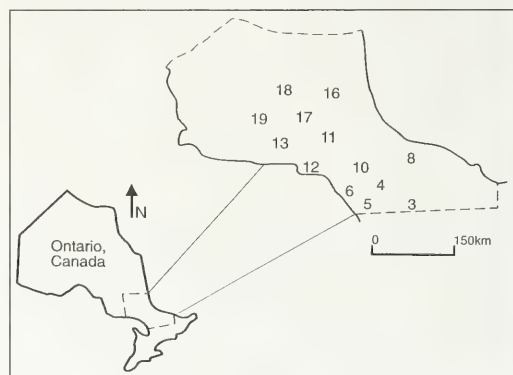


FIGURE 1. Approximate location of each 100-km² (10 km × 10 km) survey plot in central Ontario. Plot numbers correspond to CWS long-term survey plot numbers.

Joint Venture of the North American Waterfowl Management Plan). Plots 11–13 and 16–19 were surveyed during 1990 on 11–13 July and on 29 July–3 August. Plots 3–6, 8, and 10 were surveyed during 1991 on 22–25 June and on 21–28 July.

We used a Bell 206B Jet Ranger helicopter with bubble windows on the back doors or with back doors removed to increase visibility. Survey methodology was similar to that used for waterfowl breeding pair surveys (Ross 1985) except, when possible, we flew slower (<60 km/h) and lower (<15 m above ground level). The survey crew consisted of a pilot and a navigator/recorder in front and two observers in the back. Surveys were usually conducted between 7:00 and 11:00 and between 15:00 and 19:00, when wind speed was <15 km/hour, as broods are less active during the heat of the day and are more difficult to survey when the wind disturbs the water surface. We surveyed all wetlands in the survey plot. However, because this was part of a larger study on Mallards and Black Ducks (Merendino 1993), our primary emphasis was on counting Mallard and Black Duck broods, so survey effort was focused on smaller, vegetated wetlands. Survey effort on large (>20 ha), open water lakes was concentrated in shallow, vegetated (marshy) bays. Brood location, species, and number and age of ducklings (Gollop and Marshall 1954) were recorded on aerial photographs.

We used chi-square analysis to compare observed (number of different broods) vs. expected brood numbers (% breeding pairs × total broods of all species = number of expected broods) as determined from number of indicated breeding pairs from earlier

surveys for each species. Broods that were observed on both surveys, based on location, age, and number of ducklings, were only included once in chi-square analyses. Breeding pair data were obtained from Canadian Wildlife Service (CWS) breeding pair surveys conducted in May each year (Ross and Fillman 1990). We calculated mean brood size for Class Ia-IIa and IIb-III broods. Hatch date was determined from first brood observations only.

Results

1990 Surveys

We observed 109 different broods of nine species (Table 1). Overall brood density was 15.6 broods per 100-km². The percentage of dabbling duck (57%) and diving duck (43%) broods was similar to the percentage of breeding pairs, 58% and 42%, respectively. Ring-necked Duck ($\chi^2 = 13.2$, 1 df, $P < 0.01$) and Black Duck ($\chi^2 = 10.3$, 1 df, $P < 0.01$) broods were observed more than expected. Common Merganser (*Mergus merganser*) ($\chi^2 = 7.36$, 1 df, $P < 0.01$) and Common Goldeneye (*Bucephala clangula*) ($\chi^2 = 13.2$, 1 df, $P < 0.05$) broods were observed less than expected. Other species were observed roughly in proportion ($P > 0.10$) to expected frequencies.

Class Ia-IIa brood sizes ranged from 2.8 ducklings for Black Ducks to 4.6 ducklings for Wood Ducks (Table 2). Class IIb-III brood sizes ranged from 2.8 ducklings for Hooded Mergansers to 3.8 ducklings for Mallards (Table 2). No class IIb-III Wood Duck broods were observed.

Most Black Duck (69%) and Mallard (67%) broods hatched during June (Table 3). Peak hatching

TABLE 1. Number and percentage of waterfowl broods and pairs observed on 13 100-km² (10 km × 10 km) plots in central Ontario, summer 1990–1991¹.

Species	1990				1991			
	Broods		Pairs		Broods		Pairs	
	n	%	n	%	n	%	n	%
Mallard	24	22	138	21	31	28	145	16
Black Duck	26	24	87	13	19	17	138	15
Ring-necked Duck	34	31	102	16	8	7	60	7
Hooded Merganser	8	7	69	11	30	28	197	22
Wood Duck	8	7	85	13	21	19	252	28
Blue-winged Teal ²	4	4	20	3	0	0	10	1
Common Merganser	2	2	62	10	0	0	70	8
Common Goldeneye	2	2	52	8	0	0	7	<1
Green-winged Teal ³	1	<1	24	8	0	0	10	1
Other ⁴	0	0	8	1	0	0	11	1

¹Breeding pair surveys were flown in May each year. Brood surveys in 1990 were conducted on plots 11–13 and 16–19 and were flown 11–13 June and 29 July–3 August. Brood surveys in 1991 were conducted on plots 3–6, 8, and 10 and were flown 22–25 June and 21–28 July.

²*Anas discors*

³*Anas crecca*

⁴Includes Gadwall, American Wigeon, Red-breasted Merganser, and Bufflehead.

TABLE 2. Class Ia-IIa and IIB-III brood sizes for 5 waterfowl species observed on 13 100-km² (10 km × 10 km) plots in central Ontario during summer 1990 and 1991¹.

Species	1990						1991					
	Class Ia-IIa			Class IIB-III			Class Ia-IIa			Class IIB-III		
	n	x	SE	n	x	SE	n	x	SE	n	x	SE
Mallard	19	3.8	0.4	5	3.8	0.6	12	5.3	0.5	19	4.6	0.5
Black Duck	6	2.8	0.6	20	3.5	0.5	12	4.7	0.5	7	3.1	0.6
Ring-necked Duck	31	4.4	0.3	3	3.7	0.3	8	4.9	0.6	0	0.0	0.0
Hooded Merganser	4	4.5	0.1	4	2.8	0.9	28	4.6	0.5	2	4.0	1.0
Wood Duck	8	4.6	1.0	0	0.0	0.0	15	6.3	0.7	6	4.5	0.5

¹Breeding pair surveys were flown in May each year. Brood surveys in 1990 were conducted on plots 11–13 and 16–19 and were flown 11–13 June and 29 July–3 August. Brood surveys in 1991 were conducted on plots 3–6, 8, and 10 and were flown 22–25 June and 21–28 July.

for Ring-necked Ducks and Wood Ducks occurred in early July (Table 3). Peak hatching for Hooded Mergansers occurred from 16 June to 15 July (Table 3).

1991 Surveys

We observed 109 different broods of five species (Table 1). Overall brood density was 18.2 broods per 100-km². The percentage of dabbling duck (65%) and diving duck (35%) broods was similar to the percentage of breeding pairs, 62% and 38%, respectively. Mallard broods ($\chi^2 = 11.53$, 1 df, $P < 0.01$) were observed more than expected. Common Merganser broods ($\chi^2 = 9.0$, 1 df, $P < 0.01$) were observed less than expected. Other species were observed in approximate proportion ($P > 0.05$) to expected frequencies.

Class Ia-IIa brood sizes ranged from 4.6 ducklings for Hooded Mergansers to 6.3 ducklings for Wood Ducks (Table 2). Class IIB-III brood sizes ranged from 3.1 ducklings for Black Ducks to 4.6 ducklings for Mallards (Table 2). We observed no Class IIB-III Ring-necked Duck broods.

All Black Duck broods (100%) and most Mallard (90%) and Hooded Merganser broods (83%) hatched during June (Table 3). Most Ring-necked Duck broods (88%) hatched during early July (Table 3). All Wood Duck broods hatched from 16 June to 15 July (Table 3).

Discussion

Although Kirby (1980) suggested that ground monitoring was the best method for developing population indices of waterfowl breeding in forested areas, Ross (1985) developed a helicopter survey that was reliable, cost-effective, and more efficient than ground surveys of waterfowl breeding in forested regions of Ontario. We observed broods in proportion to, or greater than, expected frequencies for most breeding species, suggesting that a helicopter-based survey provides brood observations that are proportionally similar to those of breeding pairs. Although we thought that our brood survey effort was biased toward detection of dabbling duck broods, the overall percentage of broods was similar

TABLE 3. Hatch chronology (number and % of broods hatched) for 5 waterfowl species observed on 13 100-km² (10 km × 10 km) plots in central Ontario, summer 1990 and 1991¹.

Species	1990					1991				
	Period					Period				
	n	1	2	3	4	n	1	2	3	4
Mallard	24	25	42	8	25	31	58	32	10	0
Black Duck	26	38	31	19	12	19	68	32	0	0
Ring-necked Duck	34	0	9	76	15	8	0	13	87	0
Hooded Merganser	8	13	50	38	0	30	20	63	17	0
Wood Duck	6	0	38	42	0	21	0	57	43	0

¹During 1990 surveys period 1 = 1–15 June, period 2 = 16–30 June, period 3 = 1–15 July, period 4 = 16 July–3 August. During 1991 surveys period 1 = 1–15 June, period 2 = 16–30 June, period 3 = 1–15 July, period 4 = 16–31 July. Brood surveys in 1990 were conducted on plots 11–13 and 16–19 and were flown 11–13 June and 29 July–3 August. Brood surveys in 1991 were conducted on plots 3–6, 8, and 10 and were flown 22–25 June and 21–28 July.

to, or exceeded, the percentage of breeding pairs for most species, except Common Merganser and Common Goldeneye. Most species of waterfowl in northern Ontario use small headwater wetlands with well-developed littoral areas for breeding and brood-rearing (McNicol et al. 1987: 44), so the overall agreement between brood and pair percentages was not surprising. Thus, we suggest that helicopter-based surveys will provide valid production indices over the extensively forested areas of eastern Ontario, as well as other areas in eastern North America.

Our helicopter-based survey results (15.6 broods per 100 km² in 1990 and 18.2 broods per 100 km² in 1991) were similar to those (19.2 and 18.7 broods per 100 km²) reported by Parker et al. (1992) for helicopter-based surveys in New Brunswick. Gabor et al. (1995) used "mark-recapture" methods to address visibility bias of helicopter surveys and suggested a 2 × correction factor for helicopter-based surveys in northern Ontario. Assuming this is a relatively constant value we may extrapolate (# different broods × 2) our results to 31.2 and 36.4 broods per 100 km² in 1990 and 1991, respectively. Notably, these extrapolated values approach those reported by McNicol et al. (1987: 43) and Kirby (1980) for ground based surveys in forested areas of central Ontario and Minnesota, respectively.

Research is needed to quantify discrepancies between brood and indicated pair counts for Wood Ducks, Common Goldeneye, and Common Merganser. Wood Duck broods are difficult to detect (Kirby 1980) and we observed some older broods move into upland areas to avoid the helicopter. Moreover, it is probable that indicated pairs of Wood Ducks were overestimated as a result of moult migrants from southern latitudes being present during the breeding season in central Ontario. In 1990, we surveyed habitats used by Common Goldeneye (McNicol et al. 1987: 65), but we observed relatively few broods. Our reduced brood survey effort on open-water lakes, that are used by Common Goldeneye (Merendino et al. 1995) may explain the relatively few broods observed. The lack of brood observations for Common Merganser may also be due to a reduced survey effort on open-water lakes or rivers. Merendino et al. (1995) indicated that Common Mergansers used open-water lakes, and McNicol et al. (1987: 66) indicated that Common Mergansers are usually associated with wetlands > 20 ha.

Class Ia-IIa brood sizes that we report are lower than those reported for other areas (Bellrose 1980; McAuley and Longcore 1988) where ground surveys were conducted. This disparity may be partly due to difficulty counting smaller ducklings, which readily moved into cover as the helicopter approached. In contrast, Class IIb-III brood sizes that we report are similar to those reported for other areas in eastern

North America (Reed 1975; Bellrose 1980; Ringelman and Longcore 1982; McAuley and Longcore 1988; Longcore et al. 1998) where ground surveys were conducted. These similarities are probably due to larger ducklings being easier to count, as they flushed less readily, and generally moved with the hen into open water as the helicopter approached.

The similarity in sizes between Mallard and Black Duck broods lends credence to the arguments provided by Merendino et al. (1993) and Merendino and Ankney (1994) that Mallards could breed successfully in areas where they co-exist with or have replaced Black Ducks. This is further underscored by Longcore et al. (1998) who reported that sympatric Mallards and Black Ducks in Maine exhibited similar productivity.

Our data on hatch chronology for Mallards and Black Ducks are similar to those reported in Maine by Longcore et al. (1998). In both studies, most Mallard and Black Duck broods hatched during June, with peak hatching generally occurring from 1–15 June. Overall, data on hatch chronology indicate that brood surveys in central Ontario should start no earlier than 25 June to allow late-nesting (e.g., Ring-necked Ducks) to hatch broods and to allow for delayed nesting, caused by inclement weather, of early nesting species (e.g., Mallards, Black Ducks). Brood surveys should end by 25 July, after which it is difficult to distinguish early-hatched ducklings from adults. Helicopter surveys are expensive to conduct (\$750.00 per hour when we did this research), so brood surveys should be stratified based on breeding pair densities. For cost-effectiveness, a single survey in late July may provide a reliable production index for both early and late nesting species.

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Distribution and Abundance of Mountain Goats, *Oreamnos americanus*, in Westcentral British Columbia

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During autumn 1996 and 1997, we surveyed eight inventory blocks covering 6427 km² in west-central British Columbia for Mountain Goats (*Oreamnos americanus*) and estimated that a minimum of 2272 individuals occupied the area. Totals were not adjusted for sightability. For areas above the minimum elevations of goat sightings, the overall population density was 0.70 goats • km⁻². Mountain Goats occurred in groups of 1–33 animals and at elevations ranging from 500 to 2050 m. Most (87.3%) were observed in alpine or cliff areas, but many (10.7%) were observed in timbered areas, especially near the coast. The present Mountain Goat population appears healthy, but expanding forestry operations in Mountain Goat habitat and increased road access will necessitate more refined management in the near future.

Key Words: Mountain Goat, *Oreamnos americanus*, Caprinae, survey, British Columbia.

The Mountain Goat (*Oreamnos americanus*) is widely distributed across the major mountain ranges on the mainland of British Columbia. In addition to consumptive and non-consumptive uses of Mountain Goats by residents of British Columbia, our conversations with local First Nation elders revealed a long tradition of subsistence and ceremonial uses by local First Nations peoples.

Denizens of some of the most rugged and remote terrain in North America, Mountain Goats have been less vulnerable to hunters and human disturbances than other North American ungulates (Rideout 1978). However, as the economic value of timber at higher elevations has increased, resource roads have greatly increased human access in Mountain Goat habitat. As a result, Mountain Goats have become increasingly vulnerable to disturbances and over-harvesting throughout much of their range. A goal of this study was to provide wildlife managers with current inventory information to ensure that harvests by resident, non-resident and First Nations hunters are based on sound data (Demarchi et al. 1997*; Demarchi and Johnson 1998*). Prior to this survey, data on the local population of Mountain Goats were non-existent for some parts of the area and not current enough in others to allow resource management decisions to be made confidently.

Study Area

Surveys were flown in the Hazelton Mountains and the Coast Mountains in the Nass Ranges and Kitimat Ranges Ecoregions (Demarchi et al. 1990), respectively (Figure 1). Eight survey blocks have been delineated for management purposes by the provincial government and by the authors. Elevations in these rugged mountains range between

sea level and 2000 m near the coast and between 200 m and 2200 m in the eastern portion of the survey area. The Nass River and Cranberry River flow along parts of the study area's northern boundary. The study area contains zones of general open season hunting for Mountain Goats and, in the more accessible parts, limited entry hunting.

The area is dominated by the Alpine Tundra (AT) biogeoclimatic zone, with lesser amounts of the Mountain Hemlock (MH) and Coastal Western Hemlock (CWH) zones (Banner et al. 1993). Depending on local climate and topography, the CWH zone ranges between 0–1000 m; the MH zone occurs at elevations between 550–1600 m; and the AT zone occurs at elevations above 1200–1600 m (Banner et al. 1993). The climate ranges widely from maritime in the southwest to continental in the northeast. Clear-cutting of forests is the primary industry and our aerial observations during 1996–1999 indicate that logging is occurring in an increasing number of watersheds within the study area. However, the majority of watersheds in the area were undeveloped as of 1997.

The AT zone (Banner et al. 1993) has a severe climate with low temperatures, thick snowcover, and high winds. Due to the very short frost-free period, the growing season in the AT is the shortest in the province. No long-term data exist, but the overall mean annual temperature is likely below 0°C and most of the precipitation falls as snow. The rock faces, scree slopes and glaciers of this zone are mainly unvegetated. Vegetated areas are dominated by shrubs, grasses, herbs, mosses, liverworts, and lichens. Conifers are conspicuously absent from most of the AT zone, but occur in a krummholz form at lower levels in this zone. The MH and CWH

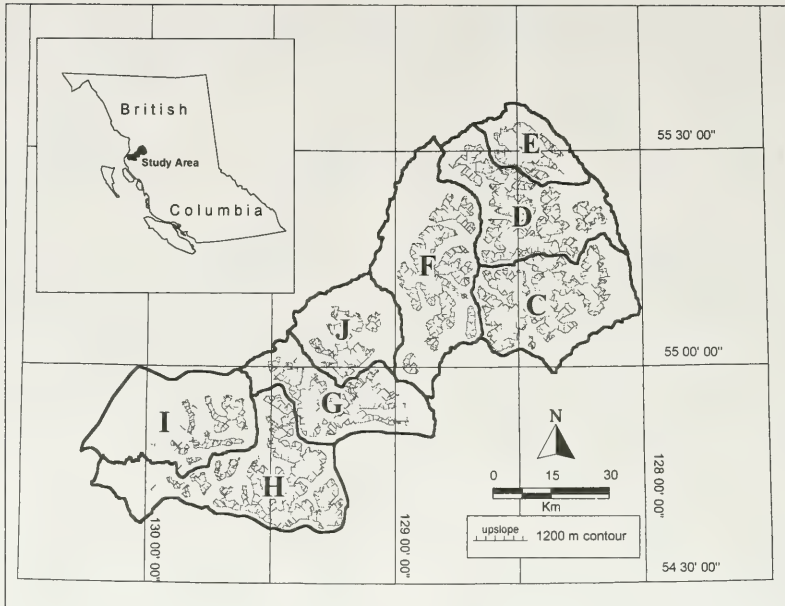


FIGURE 1. Mountain Goat survey blocks as inventoried during the fall periods of 1996 (C, D, E, F, G, H) and 1997 (J). The 1200-m contour approximates treeline.

zones are dominated by coniferous trees that are commercially harvested, including Western Hemlock (*Tsuga heterophylla*), Mountain Hemlock (*Tsuga mertensiana*), Western Redcedar (*Thuja pllicata*), and Subalpine Fir (*Abies lasiocarpa*). In the coastal areas of the CWH, lower elevations receive little snow, and in most of the zone, the soil does not freeze extensively during normal winters. Snow with a high moisture content covers most of the MH zone for 5–9 months of the year.

Methods

Between 7 September and 7 October 1996, aerial surveys were flown by three observers and a pilot in a Bell 206 Jet-Ranger helicopter. The distance to the mountainside and the ground speed varied with topography, but generally, the helicopter was < 150 m from the mountain and ground speed was < 70 km/h. In most areas, a single pass along the perimeter of a mountain block was sufficient to scan the area above treeline thoroughly. In some areas, especially near the coast, three or four passes were made across some mountain sides in order to ensure adequate coverage. Surveys were not conducted during days when poor weather compromised safety or impaired visibility.

Whenever possible, the sex and age class of the goats was recorded as per Chadwick (1983). However, the timing of the surveys did not coincide with the optimum period to conduct classification counts (Resources Inventory Committee 1997). At

the time of year when surveys were conducted, “yearlings” (i.e., ≈ 1.5 years old) were very similar in body size to subadult Mountain Goats (e.g., 2.5 years old). Accurate classification of “yearlings” requires that the helicopter approach the animals for close inspection. Such close approaches by a helicopter can disturb goats and cause injury or death because of the precipitous terrain (Côté 1996). We attempted to minimize harassment by avoiding close approaches and minimizing the amount of time spent in the vicinity of goats. As a result, a substantial proportion of yearlings were undoubtedly assigned to the “unclassified adults and yearlings” category — particularly when they occurred in herds. In some cases, the identity of sex was apparent (e.g., single adults with a kid were recorded as adult females; large adults with dirt-stained rumps were recorded as adult males). When an adult-sized individual’s sex could not be determined, it was assigned to the “unclassified adults and yearlings” category. Furthermore, if it was not possible to get a good view of an animal (e.g., beneath forest cover), it was assigned to the “unclassified” category.

A hand-held GPS unit (Magellan ProMARK X) logged the time and position (i.e., UTM coordinates and altitude) of the helicopter every 3 seconds. Sightings made by observers were recorded using a cassette recorder. Records consisted of the time of each observation, the species, the number of individuals by classification, and an estimate (nearest 50 m) of the animal’s elevation based on its location in

relation to the helicopter (according to the current reading of the on-board GPS or the helicopter's altimeter). The general habitat of each sighting was also noted. General habitat types consisted of the following: "alpine" (non-cliff areas above the treeline such as heath meadows, and krummholz areas); "avalanche slope"; "cliff" (steep rocky areas, often with trees); and "forest" (non-cliff areas dominated by non-krummholz conifers). All observations were plotted on 1:50 000 NTS maps to reduce the probability of recounting animals.

For several reasons, we did not develop any sightability correction factors (SCF) or apply them from other research to the data collected in this study. First, a variety of methods have been attempted within or near the study area to derive accurate SCFs for aerial surveys of Mountain Goats. According to one study, accurate SCFs could not be obtained (van Drimmelen 1982*). Cichowski et al. (1994) used paintballs to mark goats as part of a mark-resight approach to estimating the number of Mountain Goats in the Babine Mountains Recreation Area. Although that study showed that the paintballing technique had good potential as means of quantifying visibility bias during Mountain Goat surveys, their sightability trials were not replicated. As such, the application of an unreplicated SCF to another area, despite any similarities in habitat and survey methodology, appeared unwarranted given the large amount of inter-daily variation in Mountain Goat visibility reported by Ballard (1977), Foster (1982), and van Drimmelen (1982*). Second, the considerable differences in habitat structure between goat range in the western (coastal) and eastern (interior) portions of our study area would require that a minimum of two SCFs be derived. Third, this project had neither the time nor fiscal resources to develop SCFs. Finally, harassment stemming from a close-

flying helicopter and paint-ball gunning would cause a large amount of disturbance to the goats, subjecting them to increased stress and possible injury or mortality from falling (Côté 1996).

The elevations of Mountain Goats were summarized by group and by individual for the entire area surveyed and for each survey block. A group was considered to be a single observation of ≥ 1 animal in close proximity to each other.

Poor weather conditions forced the termination of the survey in 1996 before block J was surveyed. On 25 September 1997, a survey of block J was attempted, but was only partially completed due to poor weather conditions. The total number of goats in that block was estimated by dividing the number actually observed by the proportion of the block that was surveyed. This proportion was defined as the ratio of the linear distances along the 1200-m contour in the surveyed and unsurveyed portions of the block.

According to our observations, the management-block boundaries (Figure 1) contained substantial amounts of unsuitable goat habitat (e.g., large valley bottoms). To calculate goat densities, block-specific habitat areas were derived from the area bounded by the contour corresponding to the approximate minimum elevation ASL that goats were observed in each block. For all blocks except I, the 1000-m contour was used. For block I, the 500-m contour was used. These areas underestimate the actual area because they are independent of topographic effects.

Results

A total of 2151 Mountain Goats (Table 1) was observed during 61.3 hours of survey time between 7 September and 7 October 1996 (Demarchi et al. 1997*). A total of 98 hours of helicopter time (i.e., survey time, plus ferry time between surveys, plus flights to and from fuel caches) was used. With the

TABLE 1. Numbers and densities of Mountain Goats observed during aerial surveys in westcentral British Columbia, autumn 1996.

Block	Adult Males	Adult Females	Yearlings	Unclassified Adults and Yearlings	Kids	Total	Approx. Block Area (km ²) ^a	Approx. Habitat Area (km ²) ^a	Density (goats per km ²)
C	21	81	4	251	83	440	931	574	0.77
D	43	40	4	203	40	330	859	483	0.68
E	5	9	0	14	9	37	349	171	0.22
F ^b	37	57	11	129	46	280	1171	457	0.61
G	4	45	4	119	45	217	708	348	0.62
H	2	90	2	248	90	432	1113	537	0.80
I	41	99	7	173	95	415	747	449	0.92
1996 Total	153	424	32	1145	411	2151	5878	3042	0.71
J ^c	18	21	2	23	21	85(121) ^d	549	191	0.63

^aDoes not include topographic effects on area.

^bA small part of the southernmost portion of this block was not surveyed.

^cSurveyed in 1997.

^dCorrected total in parentheses.

TABLE 2. Mountain Goat group sizes and elevations of all individuals recorded during aerial surveys in the eight survey blocks in westcentral British Columbia, 1996.

Block	Statistics for Sightings								
	Group Size						Elevation		
	Minimum Number	Maximum Number	Median	Mean	Standard Deviation	n	Mean	Standard Deviation	n
C	1	29	2	3.4	4.6	129	1600	175	389
D	1	22	2	3.3	3.6	101	1556	163	289
E	1	10	2	2.6	2.5	14	1400	214	37
F	1	21	3	4.5	4.9	62	1572	103	275
G	1	33	1	2.4	3.9	89	1380	176	187
H	1	14	1	1.8	1.5	234	1399	202	377
I	1	8	1	1.8	1.2	232	1244	301	330
J ^a	1	10	2	2.5	2.3	85	1277	189	85

^aSurveyed in 1997.

exception of glaciers, snow cover of surveyed areas was nil. Weather conditions fluctuated during the 1996 survey, ranging from clear and sunny to light rain and snow at higher elevations. Air temperature in the mountains ranged from approximately -2° to 10°C . On 25 September 1997, 85 goats were observed during a partial survey of block J. Because the survey of block J covered an area that corresponded to approximately 70% of the area along the 1200-m contour [this contour corresponds approximately to treeline there for that block], and because the physiography was reasonably uniform as judged from a topographic map, we assumed that another 36 goats would have been observed if the survey had been completed. The block J total was therefore estimated to be 121 and the minimum number in the survey area was estimated to be 2272 (i.e., $2151 + 121$).

Goat densities varied among survey blocks, from a low of 0.22 goats $\cdot \text{km}^{-2}$ in block E to a high of 0.92 goats $\cdot \text{km}^{-2}$ in block I (Table 1). The overall density for areas surveyed in 1996 was 0.71 goats $\cdot \text{km}^{-2}$, and for all blocks combined, was 0.70 goats $\cdot \text{km}^{-2}$. For pooled blocks, average group size was 2.5 goats (SD = 3.1; range = 1–33; $n = 865$) (Table 2). Average elevation for all goats was 1460 m (SD = 238 m; range = 500–2050 m; $n = 1898$). Despite having the highest densities, there was a notable decline in group size and elevation for goat sightings in the heavily forested blocks near the coast (Table 2).

Of 1934 goats for which a habitat was recorded, 87.3% were observed in "alpine" or "cliff" habitats, but a considerable number (10.7%) was also observed in timbered areas. The remainder was recorded in avalanche tracks. Because of the reduced sightability of animals in forested habitats compared to those in open areas, the number of goats in timbered areas is probably underestimated by a greater degree than in the other three habitats. Although goats nearer the coast were observed at lower elevations (where timbered areas were more likely to occur), no clear differences in the occur-

rence of goats in timbered habitats was evident between survey blocks as a function of distance from the coast.

Discussion

During autumn 1996, Mountain Goats were widely distributed in suitable habitats between 500 m and 2050 m above sea level (ASL). The minimum mean density for the surveyed area (excluding topographic effects and including all land both below and above the lowest elevations at which goats were observed) was 0.35 goats $\cdot \text{km}^{-2}$. Excluding large areas of apparently unsuitable low-elevation habitat increased this value to 0.70 goats $\cdot \text{km}^{-2}$. Because this was the first survey of its kind done in this area, the status of the population (i.e., increasing, decreasing, or stable) is unknown. However, with limited road access in most of the area and no evidence of recent winter die-offs, we suspect that the population was robust when we surveyed it.

Unlike many mountain ungulates that remain in herds throughout much of the year, Mountain Goats normally form herds for relatively short periods of the year, and membership within such herds appears to be highly dynamic (Chadwick 1983). During summer and early autumn, adult females, yearlings, and kids form nursery groups typically consisting of up to tens of animals. At that time, most adult males occur singly or in groups of 2–3 animals. Group size of ungulates is strongly affected by habitat (Putman 1988). For example, the large open spaces of the alpine tundra are more conducive to the formation and maintenance of larger herds than are the patchily distributed rocky outcrops and smaller alpine expanses observed nearer the coast. Therefore, the smaller average group sizes and lower elevations of goats observed nearer the coast likely reflect the large difference in gross habitat structure that occurs there. Our observations indicated that for each survey block, the ratio of rocky outcrops and avalanche tracks below treeline versus amount of alpine tundra

habitat was generally higher near the coast than in interior areas.

Sightings of goats in forested habitats throughout the study area suggest that, even during the non-winter period, these habitats play important roles in the species' ecology. Several researchers have documented the use of timbered areas by Mountain Goats (Hebert and Turnbull 1977; Schoen and Kirchoff 1981; Foster 1982; Chadwick 1983; Fox et al. 1989) and the role of timbered areas may change across the seasons. For example, Foster (1982) hypothesized that the abundance of biting insects in the spring forced Mountain Goats to seek refuge in heavily timbered areas. Foster (1982) and Stevens (1979; cited in Foster 1982) concluded that areas supporting dense stands of timber were also used by Mountain Goats as thermal cover during the summer. Timbered areas may provide important security cover (particularly for adult males) during fall when hunting pressure occurs (Foster 1982). Perhaps the most important use of timbered areas occurs during winter when deep snowpacks at high-elevation areas (particularly near the coast) force Mountain Goats to descend to lower elevations where they are more likely to find cover and forage beneath the crowns of large coniferous trees (Hebert and Turnbull 1977; Schoen and Kirchoff 1981; Foster 1982; Fox et al. 1989).

The Mountain Goat's reliance on rugged terrain for security cover appears to be an effective strategy to reduce predation by Grizzly Bears (*Ursus arctos*), Gray Wolves (*Canis lupis*), Cougars (*Puma concolor*), and other mammals (Chadwick 1983). However, it is largely ineffective against rifle-based hunting. As a result of liberal harvest regulations and the rapid expansion of access into remote mountain areas for forestry, mineral exploration, and recreation, some Mountain Goat populations were overharvested before wildlife managers were able to respond to the problem (Foster 1976; Phelps et al. 1976*; Kuck 1977; Chadwick 1983). The effects of access developments on goats are now well understood by biologists and wildlife managers, though effective provincial policies to manage access in British Columbia are still lacking.

Mountain Goat management in British Columbia draws on several approaches to conserve populations. Area and access closures, timing of hunting seasons, bag limits, and use of limited entry permits are common means by which goat harvests are regulated. In the past, most Mountain Goat ranges did not overlap stands of high quality timber on operational sites. As opportunities to harvest trees at lower elevations have declined and markets for wood products have expanded, it has become more economical to harvest trees on sites formerly considered uneconomical or marginal. It is these latter areas where the potential is greatest for forestry to have negative impacts on goat populations. These impacts are

largely due to modifications to forested habitat and improved human access to high-elevation forests and alpine areas used by goats.

The importance of forested habitats for Mountain Goats and their vulnerability to over-harvest reinforces the need to integrate forest management with Mountain Goat management — especially as the supply of low-elevation timber declines, and market forces and technological advances make it economical to harvest trees in or near areas inhabited by Mountain Goats. Expanding forestry operations in westcentral British Columbia and other such areas will continue to pose challenges to resource managers attempting to conserve pre-development populations in a post-development environment.

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Sexing American Bitterns, *Botaurus lentiginosus*, Using Morphometric Characteristics

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Morphometric measures from 1995–1998 were used to develop a discriminant function that provides investigators with a practical, non-destructive technique for sexing American Bitterns (*Botaurus lentiginosus*). Thirty-two males were lured into mirror traps and mist nets using tape-recorded territorial vocalizations and 17 females were captured at nest-sites using long-handled dip nets. Sex of captured birds was known because only males respond aggressively to territorial vocalizations and only females incubate nests. Average morphometric measures were greater for male than female American Bitterns with overlap between the sexes. Tarsus length was the single most useful measurement in discriminating between sexes, correctly identifying 100% of individuals used to construct the function and 71.4% of birds that were not used in model development (hold-out test data set). The addition of short bill length measurements increased the proportion of correctly classified individuals in the hold-out test data set to 76.2% for males and 85.7% for females. This technique will enable field ecologists to separate population and behavioral data according to sex.

Key Words: American Bittern, *Botaurus lentiginosus*, discriminant function analysis, morphometric measurements, sex criteria, wetland birds, Minnesota.

Declines in American Bittern (*Botaurus lentiginosus*) populations over the last three decades led to its listing as a migratory nongame bird of management concern (USFWS 1995; Sauer et al. 1997). Conservation programs for American Bitterns have not been implemented because investigations of nearly every aspect of bittern ecology are lacking (Duebbert and Lokemoen 1977; Gibbs et al. 1992; Svedarsky 1992; Azure 1998). Studies into the most basic aspects of population or behavioral ecology require that investigators correctly sex study animals. Obtaining such information without sacrificing individuals for direct gonad examination is challenging because American Bitterns lack plumage characteristics by which sexes can be recognized. In this study, we use morphometric differences between known male and female birds to calculate a mathematical function that provides investigators with a practical, non-destructive technique for sexing American Bitterns.

Methods

Our principle study site, Agassiz National Wildlife Refuge (ANWR), is a 24846-ha area along the transition from prairie to coniferous forest in north-west Minnesota. Our secondary study site was a 1031-ha Wildrice (*Zizania aquatica*) farm of the Red

Lake Band of Chippewa Indians, located 100 km southeast of ANWR. In the summers of 1995–1998, we broadcast tape-recorded territorial vocalizations (i.e., pumping calls) of American Bitterns to lure males into mirror traps and mist nets (Brininger 1996). Incubating female American Bitterns were captured on nests using long-handled dip nets. Sex of captured American Bitterns was positively determined because only males respond aggressively to territorial vocalizations (Brininger 1996) and only females incubate nests and feed young (Gibbs et al. 1992).

Upon capture, 32 male and 17 female American Bitterns were weighed to the nearest gram on an OHAUS balance scale and the following 13 morphometric measures were obtained using a digital caliper (nearest 0.1 cm): long and short bill lengths from the anterior and posterior margins of the nostril to the tip of the bill, exposed culmen length, bill widths anterior to the nostrils and dorsal to the cere, head width posterior to the eyes, tarsus length, length of the middle toe and width of the second phalange, length and width of the nail on middle toe, wing chord and tail length (Table 1). Seven of 14 measurements (Table 1) were used in analyses after eliminating weight, tail length, long bill length and width, short bill width, exposed culmen length and wing chord

TABLE 1. Means (\pm SE) and Coefficients of Variation (CV) of morphometric measurements obtained from male and female American Bitterns in northwest Minnesota, 1995–1998.

Morphometric measures ^a	Male (n = 31)			Female (n = 17)		
	\bar{x}	SE	CV	\bar{x}	SE	CV
Measures used in model construction						
Tarsus length	9.12	0.06	3.5	8.49	0.06	3.0
Short bill length	5.52	0.05	4.6	5.21	0.09	6.7
Head width	2.61	0.02	4.6	2.39	0.02	2.9
Middle toe length	7.84	0.07	4.8	7.28	0.06	3.4
Middle toe nail length	2.10	0.03	7.7	2.01	0.07	13.6
Second phalange width	0.40	0.01	11.3	0.35	0.01	10.7
Middle toe nail width	0.29	0.01	12.4	0.27	0.01	11.2
Measures excluded from model to reduce collinearity						
Weight (g)	928	17.26	10.4	569	8.81	6.2
Tail length	9.42	0.15	8.8	8.09	0.19	4.5
Long bill length	7.24	0.11	8.1	6.53	0.06	4.1
Long bill width	1.46	0.02	7.4	1.42	0.02	6.3
Short bill width	1.01	0.01	6.4	0.91	0.02	8.0
Exposed culmen length	7.58	0.07	4.7	7.00	0.10	4.7
Wing chord length	27.82	0.17	3.3	24.92	0.27	4.5

^aMeasurements other than weight (g) were measured to the nearest 0.1 cm.

length from the data set to reduce collinearity ($r > 0.5$).

Stepwise discriminant function analysis (SYSTAT 8.0; Wilkinson 1998) was performed on measurements from 10 randomly selected individuals of each sex (analysis data set), entering at each step the measurement that added the most separation between the sexes. Wilks' lambda was used to test significance of our classification functions (Wilkinson 1998). We used a jack-knife statistical procedure (also called the leave-one-out analysis; Lachenbruch and Mickey 1968) where each individual was classified using a function derived from the sample less the individual being classified as one method of cross-validating our ability to discriminate between sexes. This method produces unbiased classification rates of discriminant functions (e.g., Seber 1984). We also cross-validated our predictive capability by classifying 21 male and 7 female American Bitterns that were not used in model construction (i.e., hold-out test data set). One male with a bill length > 2 standard deviations from the mean was excluded from analyses.

Results

Average morphometric measurements were greater for male than female American Bitterns with overlap between the sexes (Table 1). Tarsus length (Figure 1) was the single most useful measurement in discriminating between sexes, correctly identifying all individuals used to construct the function (i.e., analysis data set) (Table 2). Equations using tarsus length (Wilks' Lambda = 0.37, $F = 30.05$, $df = 1, 18$, $P < 0.001$; Table 2), where individuals are classified according to the largest value of classifica-

tion functions, correctly classified 71.4% of both male and female American Bitterns that were not used in model construction (i.e., hold-out test data

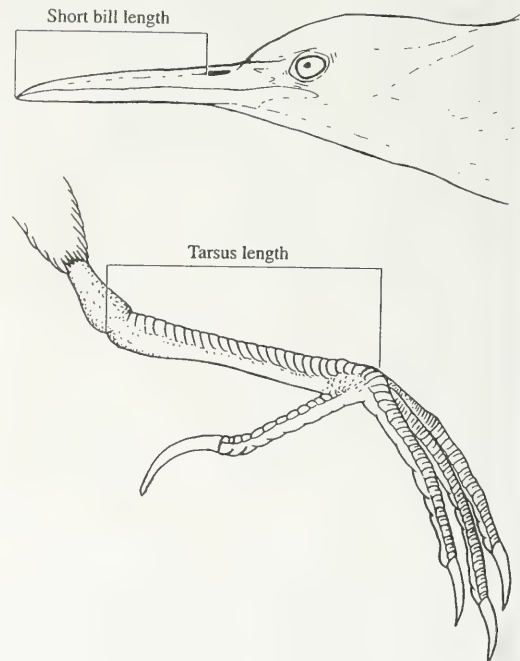


Figure 1. The two "best" morphometric measurements used in discriminant functions to sex American Bitterns were short bill length and tarsus length.

TABLE 2. Classification functions for discriminating between sexes of American Bitterns in northwest Minnesota, 1995–1998.

Variable name	Classification Function Coefficients	
	Male	Female
Tarsus length only ^a		
Constant	-742.88	-651.43
Tarsus length	162.85	152.49
Apparent classification rate	100%	100%
Jack-knifed classification rate	100%	100%
True classification rate	71.4%	71.4%
Tarsus and short bill lengths ^b		
Constant	-893.33	-783.82
Tarsus length	162.34	152.01
Short bill length	55.03	51.62
Apparent classification rate	100%	100%
Jack-knifed classification rate	100%	100%
True classification rate	76.2%	85.7%

^aWilks' Lambda = 0.37, F = 30.05, df = 1, 18, P < 0.001.

^bWilks' Lambda = 0.33, F = 16.92, df = 2, 17, P < 0.001.

set). The addition of short bill length (Wilks' Lambda = 0.33, F = 16.92, df = 2, 17, P < 0.001; Figure 1), increased the proportion of correctly classified individuals in the hold-out test data set to 76.2% for males and 85.7% for females (Table 2). On the basis of Wilks' Lambda values and number of correctly classified cases, inclusion of additional variables into functions was unwarranted.

Discussion

Tarsus and bill length measures provide a practical, non-destructive method for sexing American Bitterns. Advantages of using tarsus and bill lengths outweigh minor increases in predictive capability (<5%) that results with inclusion of different or additional measurements. Tarsus and bill length measures (Figure 1), do not vary with fluctuations in body condition that occur seasonally due to breeding (e.g., egg laying), molting and diet. Although male American Bitterns typically weigh more than females (Gibbs et al. 1992), we reduced collinearity by excluding body weight (Table 1) because weights of male American Bitterns radio-collared in May and recaptured in August declined 200–250 g (D. Azure, unpublished data); making body weight a potentially poor predictor of sex. Similarly, Zavalaga and Paredes (1997), in developing a function for classifying sex of Humboldt Penguins (*Spheniscus humboldti*), excluded body mass from their discriminant function because penguin weights varied significantly between seasons (CV = 13.6%). In this study, body weight of male American Bitterns was the most variable measure (CV = 10.4%) of those excluded from analyses (Table 1).

We were unable to correctly sex all individuals because morphometric measures of 8 males in the

hold-out test data set were consistently low compared to average measurements for all male bitterns. Each incorrectly classified male had a tarsus length <9 cm and no male correctly classified in the hold-out data set had a tarsus length <9 cm. Although females captured while incubating nests or feeding young were known to be adults, we were unable to verify age of male American Bitterns because subadults as well as adults respond to territorial vocalizations. We suspect discrepancies in morphometric measures of male American Bitterns are age-related. Males with tarsus lengths <9 cm were likely subadults captured while performing mating rituals and courtship displays. While this technique has its limitations, it will enable field ecologists to separate population and behavioral data according to sex.

Acknowledgments

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Notes

A Range Extension for the Meadow Jumping Mouse, *Zapus hudsonius*, in Southwestern Alaska

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Peirce, Kellie Nolan, and Joshua M. Peirce. 2000. A range extension for the Meadow Jumping Mouse, *Zapus hudsonius*, in southwestern Alaska. *Canadian Field-Naturalist* 114(2): 311.

A survey of small mammals in southwestern Alaska documented a new record for the Meadow Jumping Mouse, (*Zapus hudsonius*) from river mile 28 on the Goodnews River in southwestern Alaska in the Togiak National Wildlife Refuge.

Key Words: Meadow Jumping Mouse, *Zapus hudsonius*, new record, range, survey, southwestern Alaska.

Little is known about small mammal communities in southwestern Alaska (Nolan and Peirce 1996). From 15 July to 3 September 1995 we trapped small mammals along the Goodnews River in Togiak National Wildlife Refuge, Alaska. We used snap traps, pitfall traps and live traps to collect specimens. A total of 851 trap nights yielded two specimens of the Meadow Jumping Mouse (*Zapus hudsonius*).

The survey was conducted at river mile 28 on the Goodnews River, located approximately 150 air kilometers from Dillingham in southwestern Alaska. The region is characterized by willow (*Salix* spp.), bog and tussock tundra in riparian areas and alder (*Alnus* spp.) and dry tundra in higher elevation mountainous terrain.

The first specimen of *Z. hudsonius* was captured on 31 July in a snap trap set in a cottonwood grass habitat. The cottonwood grass habitat consisted of approximately 50% mature cottonwoods, *Populus* spp., 45% *Poa* spp., and 5% immature *Salix* spp. The second specimen was captured in a snap trap on 11 August in a closed low willow shrub habitat (Viereck et al. 1992). Both specimens were sent to the University of Alaska Fairbanks Museum for species verification.

The capture of *Z. hudsonius* within the refuge represents a new record for the species (59°17'N, 161°06'W). Hall (1981) shows a specimen collected at Lake Aleknagik (59°16'N, 158° 37'W) approximately 125 km east of the study site. A specimen catalogued at the University of Alaska Fairbanks Museum (CN 22712) was captured approximately

135 km north of our study site at Nyac (60°59'N, 160°04'W). *Zapus hudsonius* were also collected at Cape Peirce (58°34'N, 161°45'W), Togiak National Wildlife Refuge, during the summer of 1994 and placed in a collection there (Andy Aderman, personal communication). These data extend the range shown by Hall (1981) and verify the suggestion of Manville and Young (1965) that *Z. hudsonius* occurs in southwestern Alaska.

Acknowledgments

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Road Densities and Gray Wolf, *Canis lupus*, Habitat Suitability: an Exception

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Merrill, Samuel B. 2000. Road densities and Gray Wolf, *Canis lupus*, habitat suitability: an exception. *Canadian Field-Naturalist* 114(2): 312–313.

Several studies have suggested that Gray Wolf populations are jeopardized at road densities > 0.58 km/km². One landscape model predicting wolf occupancy based on road densities which were not higher than 0.45 km/km² (Mladenoff et al. 1995) has been supported with field data (Mladenoff et al. 1999). In one example in central Minnesota, wolves are breeding successfully in an area with a road density of 1.42 km/km². This situation illustrates the point that road density is an index of high-speed vehicles and human attitudes, and there are situations when road density alone is not an accurate index of wolf habitat suitability.

Key Words: Gray Wolf, *Canis lupus*, road density, habitat suitability, index, Minnesota.

Gray Wolves (*Canis lupus*) have been recolonizing parts of their former range in the northern United States for the last 25 years, and in recent years have moved into many semiwilderness and agricultural areas (Mech 1995). Biologists and managers have become interested in understanding needs of wolf populations in these transitional areas. Several studies in the 1980s suggested that wolf populations could not survive in areas with road densities > 0.58 km/km² (Thiel 1985; Jensen et al. 1986; Mech et al. 1988). More recently, established wolf populations have been identified in areas with road densities as high as 0.72 km/km² (Mech 1989; Fuller 1989).

However, a landscape model in Mladenoff et al. (1995) suggested that suitable wolf habitat in Wisconsin was restricted to areas with road density not exceeding 0.45 km/km² in the overall pack area, and 0.23 km/km² in pack core areas (areas containing sensitive den and rendezvous sites). This suggestion was later supported with field data showing that the model correctly classified 18 of 23 newly established packs. The highest road density in an area containing a successful pack was 0.71 km/km² (Mladenoff et al. 1999). I report on an exception to this trend, an established wolf population in a fragmented area of Minnesota with a road density of 1.42 km/km², and discuss road density as an index of wolf habitat suitability.

Camp Ripley (Ripley) is a 214 km² National Guard Training Site in Little Falls, Minnesota (46°N, 95° W). The terrain is generally flat, and the major cover is northern hardwood forest (primarily *Quercus*, *Populus*, and *Betula* spp.) interspersed with large open areas (grasslands, wetlands, and military firing ranges). Ripley is at the prairie-forest transition zone of central Minnesota. It is surrounded on the east, west, and south by agricultural lands, and on the north by forest land interspersed with

agricultural development. Roads at Ripley are traveled by few vehicles for about 50% of the year, but carry thousands of vehicles per month from April through September. Public access to Camp Ripley is limited, so wolves at Camp Ripley are less vulnerable to mortality from human hunters than elsewhere in Minnesota.

Because the meaning of "roads" is variable, I have adopted the definition used in Mladenoff et al. (1995): "Permanent roads (highways, other paved roads, and improved unsurfaced roads) are those requiring routine maintenance and are accessible year-round by 2-wheel drive vehicles (no four-wheel drive tracks or trails)." The definition also states that "roads usually appear as solid lines on a USGS 1:100 000 map." This latter criterion was difficult to meet at Ripley because USGS maps of the area are old relative to the current extent of roads. Area of Ripley, road classes, and road lengths were obtained from databases maintained by the Minnesota Department of Military Affairs. Using ArcView GIS (ESRI, inc., Redlands, California), road lengths of different size classes were summed and compared to area. The wolf population at Ripley was monitored using VHF, GPS, and satellite radiotelemetry.

Radiotelemetry at Camp Ripley since 1996 has shown over 80% of radio-locations to be within the Ripley boundary. Home range boundaries have included all portions of the base, and wolf dens and rendezvous sites have been found on the base. The alpha pair produced litters each year from 1994–1999 (Table 1). Actual pup numbers may have been higher each year than indicated in Table 1.

Road density at Camp Ripley is 1.42 km/km². Smaller roads at Camp Ripley are abundant; if an additional class of roads were included, the road density index would be 3.7 km/km². Even though many of the roads in this class fit the Mladenoff et al. (1995) road definition, this class was not included

TABLE 1. Evidence of wolf breeding activity observed at Camp Ripley National Guard Training Site in Little Falls, Minnesota from 1995–1998.

Year	Number of pups observed	Rendezvous site observed?	Den observed?
1994	4	No	No
1995	4	Yes	No
1996	6	Yes	No
1997	3	Yes	Yes
1998	5	No	No
1999	3	No	Yes

in the index. The more conservative estimate of 1.42 km/km² of roads at Camp Ripley is more than double previous estimates of maximum road densities survivable by wolf populations.

However, evidence of wolves reproducing in an area is not evidence by itself that a population can be sustained there. Many wolves dispersing from Camp Ripley are hit by cars or illegally shot or trapped (Merrill 1999). Nevertheless, despite substantially higher road density than previously stated maximums, the wolf population at Camp Ripley is surviving. Some of this success may be due to immigration from source areas in northern Minnesota, but litters have been raised and dispersal has occurred each year, making it difficult to label Camp Ripley a population sink.

This exception to the pattern observed in Mladenoff et al. (1999) between road density and wolf habitat suitability is probably not related to volume of human use. Camp Ripley trains about 40 000 troops per year, and vehicle traffic is heavy for over half of each year. Therefore the exception is probably related to speed of the traffic (speed limits on the base are 40 km/h) and attitudes of humans the wolves encounter. Troops do not shoot wildlife, and troop education programs are in place that illustrate the value of wolves in natural systems. Despite high road density and vehicle traffic, there is no record of any wolves being shot at Camp Ripley. This situation illustrates the point that road density is an not an index of human contact, but an index of high-speed vehicles and human attitudes.

The exception at Camp Ripley does not challenge the pattern in Mladenoff et al. (1999); rather it

makes the small, but additional point that some areas with high road density and low human use do not fit the model. Resource planners considering use of road density to identify areas suitable for wolves should be aware of this, especially if the areas contain military lands or other lands where human attitudes towards wolves are known to be generally favorable.

Acknowledgments

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An Aggregation of Overwintering Leopard Frogs, *Rana pipiens*, and Common Map Turtles, *Graptemys geographica*, in Northern Vermont

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Ultsch, Gordon R., Terry E. Graham, and Carlos E. Crocker. 2000. An aggregation of overwintering Leopard Frogs, *Rana pipiens*, and common Map Turtles, *Graptemys geographica*, in northern Vermont. *Canadian Field-Naturalist* 114(2): 314–315.

An aggregation of at least several dozen Northern Leopard Frogs was observed in November 1998 at a previously described Common Map Turtle hibernaculum in the Lamoille River, Vermont. The frogs were sometimes under the turtles and were always exposed to well-oxygenated water. We suggest that frogs that overwinter submerged require a high-PO₂ microenvironment, and that this requirement overrides other considerations, such as avoidance of predators.

Key Words: Northern Leopard Frog, *Rana pipiens*, Common Map Turtle, *Graptemys geographica*, overwintering, hibernation, aquatic respiration, Vermont.

Ranid frogs in cold temperate climates, other than the Wood Frog (*Rana sylvatica*), which is freeze-tolerant, only occasionally overwinter on land; aquatic overwintering is the rule (reviewed by Pinder et al. 1992). Overwintering in liquid water eliminates freezing and desiccation challenges that must be met during terrestrial hibernation; however, frogs must then cope with problems of gas exchange, ionic regulation, and water balance. Frogs, and probably most amphibians, are generally anoxia-intolerant, even at cold temperatures (Christiansen and Penney 1973; Pinder et al. 1992), although they can tolerate a significant hypoxia for months while submerged (Boutilier et al. 1997; Donohoe and Boutilier 1998). Laboratory studies describing anoxia intolerance of overwintering frogs have been supported by reports of anoxic winterkill of frogs (Olson 1932; Manion and Cory 1952; Bradford 1983). Anoxia intolerance would seem to rule out overwintering while buried in mud, as mud is anoxic.

Experimental and field studies thus suggest that frogs that overwinter submerged must be exposed to water with a high enough PO₂ to drive O₂ diffusion via extrapulmonary pathways at a rate great enough to prevent a lethal accumulation of anaerobic end-products. However, there are relatively few reports of the microenvironments of overwintering frogs, and most of those do not provide data on ambient PO₂.

We have been collecting Common Map Turtles (*Graptemys geographica*) by SCUBA diving at a hibernaculum in the Lamoille River, Chittenden County, in northern Vermont (Graham and Graham 1992). During an exploratory and collecting site visit on 21–23 November 1998, approximately 100 map turtles were observed resting on the bottom of the river at depths of approximately 6–8 m. The air temperature was unseasonably warm at 16°C and ice had

not yet formed on the river, but previous cold spells had reduced the water temperature, which was only 2°C; dissolved O₂ was near saturation. As had been the case during previous years, the turtles were on, rather than in, the substrate, resting exposed singly or in small groups on sand, gravel, or rock ledges, in crevices between rocks, and beneath logs. At least several dozen Northern Leopard Frogs, *Rana pipiens*, were found in the same area. Unlike the turtles, no frogs were found away from cover. The frogs were most commonly wedged into rock crevices, but they were also often located under turtles, which they apparently considered to be just another rock. In one location, for example, 10–12 frogs were located in a depression under a group of 5 or 6 adult female map turtles. The turtles were quite responsive to the divers, and dispersed when divers approached within a meter or so, by walking off, or in a few cases, swimming. In contrast, the frogs, while not torpid and capable of movement, were not nearly as mobile as the turtles and were easily captured.

The site was also visited once each month in December through March, but we did not search for frogs, as the purpose of each visit was to collect three map turtles as rapidly as possible for blood sampling, and then to leave the site to take the samples to the laboratory for analysis. In addition, low visibility made chance observations of frogs unlikely; they may well have been present, but we cannot be certain.

Emery et al. (1972) also used SCUBA gear to observe overwintering *R. pipiens*. During under-ice dives in March in a pond in Ontario, Canada, they found them in pits that the frogs apparently excavated. The frogs were visible and largely exposed to the water, which was 0–2°C with a PO₂ of about 80 mmHg. These authors found that frogs become an

increasingly important part of the diet of trout during winter; thus exposure to predation risk is apparently outweighed by the requirement for a well-oxygenated overwintering site. Cunjak (1986) also observed overwintering in Ontario *R. pipiens*, but in a stream environment. The frogs were mostly located among rubble on the bottom, where water with an O_2 content that was close to air-saturation passed over their hibernaculum continuously; however the rubble was coarse enough that the frogs were better able to hide from view than in the situation reported by Emery et al. (1972). As in our observations, Cunjak (1986) also found the frogs to be relatively immobile and easily captured.

The map turtles may have fidelity to specific hibernacula. We attached sonar transmitters to 15 map turtles at the hibernaculum in the autumn of 1997, and at least seven of those returned the following autumn (it is possible that some transmitters were lost among the other turtles, so more than seven may have returned). Hibernaculum site fidelity among the Leopard Frogs is still an open question. One of us (TEG) has visited this site during seven recent winters from 1989–1998, and on at least three occasions (mostly in October and November) has observed solitary adult Leopard Frogs (a group of two on one occasion) resting on the bottom among cottonwood leaves, as well as occasional Red-spotted Newts, *Notophthalmus viridescens*, and a single Mudpuppy, *Necturus maculosus*. However, this is the first time that a concentration of frogs has been noted at this site, which suggests that hibernaculum selection by the frogs is likely more opportunistic than by the turtles. We suggest that the factor of most importance in the selection of a hibernaculum among frogs that overwinter underwater is a continuous supply of well-oxygenated water about the frogs (we found that PO_2 remains $\geq 80\%$ of saturation throughout the winter at this site, even during extended periods of ice cover), and that once such a site is located, the animals will hide themselves as well as possible within the restrictions of their O_2 requirements. A similar conclusion has been drawn by Lamoureux and Madison (1999) for Green Frogs (*Rana clamitans*), which they tracked throughout a winter in New York.

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The Land Snail *Cryptomastix germana* (Gastropoda: Polygyridae) in the Queen Charlotte Islands, British Columbia: A Range Extension North from Vancouver Island

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Forsyth, Robert G. 2000. The land snail *Cryptomastix germana* (Gastropoda: Polygyridae) in the Queen Charlotte Islands, British Columbia: a range extension north from Vancouver Island. *Canadian Field-Naturalist* 114(2): 316–317.

The coastal land snail *Cryptomastix germana*, not previously known to occur north of Vancouver Island, is reported from the Queen Charlotte Islands, British Columbia.

Key Words: *Cryptomastix germana*, Polygyridae, terrestrial gastropods, range extension, Queen Charlotte Islands, British Columbia

Cryptomastix germana (Gould in W. G. Binney, 1851), the Pygmy Oregonian, is a small polygyrid land snail inhabiting the coastal regions and lowland valleys from Coos Bay, Oregon, to British Columbia (Pilsbry 1940; Vagvolgyi 1966) which has been variously treated taxonomically. Pilsbry (1940) made distinctions between northern and southern populations of *Triodopsis* (*Cryptomastix*) *germana* (Webb [1954] later elevated *Cryptomastix* to full generic rank) and applied the subspecific name *T. germana vancouverinsulae* (Pilsbry and Cooke, 1922) for populations north of the Columbia River. The presumed differences between *T. germana vancouverinsulae* and the nominal subspecies were said to intergrade (Vagvolgyi 1966; Branson 1977), contrary to the opinion of Pilsbry (1940), and Vagvolgyi treated *T. germana vancouverinsulae* as a synonym. *C. germana* is the type and presently only known species in the genus-level taxon *Micranepsia* Pilsbry, 1940 (described as a "section" of *Cryptomastix* and recently raised subgeneric status [Emberton 1995]). Some dissections of British Columbia and Washington material done in the 1970s have within them variation in the genitalia that has not been thoroughly investigated (F. W. Grimm, personal communication).

On the southwest coast of British Columbia, *C. germana* is a widespread species of moderate abundance in deciduous or mixed deciduous-coniferous woods where it lives under logs and in leaf litter. During wet weather this snail has also been collected high off the ground on fronds of the Sword Fern (*Polystichum munitum*). Cameron (1986) found that *C. germana* showed a strong association with damp conditions.

On the mainland of British Columbia, *Cryptomastix germana* has previously been reported from the valley of the Chilliwack River (Whiteaves 1902; Cameron 1986), Popkum (Cameron 1986), University of British Columbia Endowment Lands (Cameron 1986), and Stanley Park, Vancouver (Pilsbry 1940). On Vancouver Island, there are pub-

lished records from Bamfield, Menzies Bay, Elk Falls, Horne Lake (all Cameron 1986), Cameron Lake (Pilsbry and Cooke 1922; Pilsbry 1940; Cameron 1986), Sproat Lake (Cameron 1986), Cowichan River (Hanham 1914), Goldstream Provincial Park (Branson 1980), south of Union (Pilsbry 1940), and near Victoria (Pilsbry 1940). The most northern of these localities is Menzies Bay on Vancouver Island (circa 50°07'N, 125°23'W).

Cryptomastix germana is here reported from the Queen Charlotte Islands for the first time. Its presence there is based on a specimen collected on 8 May 1995 at Moresby Camp on Moresby Island (circa 53°03'N, 132°02'W). This record represents a significant range extension north from the previous northernmost locality on Vancouver Island, a distance of approximately 560 km (on a bearing of 287°). It was collected with *Vespericola columbianus* (I. Lea, 1838), Northwest Hesperian; *Haplotrema vancouverense* (I. Lea, 1839), Robust Lance-tooth; and *Ancotrema sportella* (Gould, 1846), Beaded Lance-tooth, from under a fallen log in a wooded area around Moresby Camp. This locality, an abandoned logging camp now used as a forest service camp site and landing, has been extensively disturbed by human activities and is dominated by deciduous trees and young conifers. Red Alder (*Alnus rubra*) is abundant.

The possibility that *C. germana* is introduced into the Moresby Camp appears very unlikely, since *C. germana* was sympatric with other native coastal land snails, none of which show a propensity to be introduced. The presence of these species at Moresby Camp suggests that they are capable of surviving in or recolonising sites substantially modified by logging activities.

The specimen, which is fully adult with a well-developed apertural denticle and flared outer lip, measures 4.4 mm in height by 6.8 mm in width (exclusive of the lip). There are approximately $4\frac{3}{4}$ whorls, counted by the method of Kerney and Cameron (1979). The periostracal hairs are largely

worn off, which has not been found to be the usual condition in other British Columbia material studied. The specimen is preserved as a dry shell only and is deposited in the Royal British Columbia Museum (Victoria) (999-00069-001).

The Queen Charlotte Island record is significant since it extends the known distribution of the species north from Vancouver Island, thus adding a considerable distance to the north-south range of this species. Moreover, the Queen Charlotte Island record suggests that *Cryptomastix germana* probably occurs elsewhere along the northern coast of British Columbia, a region of difficult access that requires further investigation.

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Successful Release of a Wild Wolf, *Canis lupus*, Following Treatment of a Leg Injury

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Thiel, Richard P. 2000. Successful release of a wild Wolf, *Canis lupus*, following treatment of a leg injury. *Canadian Field-Naturalist* 114(2): 317-319.

I report a case of a wild Wolf with a debilitated right front leg, injured in a leg-hold trap, that survived a minimum of 4.5 years following surgical repair and escape into a wildlife area 50 km from its natal pack territory in Wisconsin.

Key Words: Gray Wolf, *Canis lupus*, injury, leg-hold trap, lone wolf, rehabilitation, Wisconsin.

Two studies have evaluated the types of injury to Gray Wolves caused by research traps (Kuehn et al. 1986; Schultz et al. 1996). Little information is available on the treatment and successful return of injured Wolves to the wild (Mech et al. 1984; Schultz et al. 1999). Such information is warranted where Wolves are endangered (i.e., the U. S. Endangered Species Act of 1973 imposes a 45-day limit on retaining wild animals in captivity) and in recovery programs where valuable captive Wolves are used to establish wild populations. This observation documents the survival of a wild Wolf in Wisconsin treated for a serious trap-related injury.

A 39 kg, young adult (> 1 year) male Wolf (501M) sustained torn ligaments and an elbow dislocation to its right front leg on 21 May 1995 after being captured in a leg-hold trap in Jackson County, Wisconsin as part of the state's Wolf monitoring program (Wydeven et al. 1995). The Wolf was taken to a local veterinary clinic where the diagnosis was confirmed. Arrangements were made for its transfer to the University of Wisconsin, School of Veterinary Medicine, in Madison for surgery. That evening the joint dislocation was repaired with artificial ligaments during a 3.5 hour surgical procedure. Humeral cartilage that had been torn off could not be

replaced. Wolf 501M was transferred to a holding pen at Sandhill Wildlife Area (SWA), 50 km east of the Wolf's natal pack territory, 24 h after surgery and escaped on 23 May.

Study Site

The 36 km² Sandhill Wildlife Area is surrounded by a 3 m tall, deer-proof woven-wire fence. Sandhill consists of 50 percent upland forests of oak (*Quercus* spp.) and aspen (*Populus* spp.), and 50 percent wetlands. Deer (*Odocoileus virginianus*) densities varied from 10.5 to 11 deer per km² between winter 1995–1996 and 1997–1998 as estimated by hunter harvest registrations, sex-age kill calculations, annual fall trail counts, and biannual helicopter surveys (Creed and Haberland 1980, Wisconsin Department of Natural Resources - SWA files). Beaver (*Castor canadensis*), Cottontail Rabbit (*Sylvilagus virginianus*), Snowshoe Hare (*Lepus americanus*) and Raccoon (*Procyon lotor*) - all potential Wolf prey - are present on SWA. No other Wolves inhabited SWA at the time of 501M's escape.

Methods

Personnel noted whether Wolf 501M used its injured limb when tracks were encountered during the first six months following its escape. Wolf scats were differentiated from those of Coyotes (*Canis latrans*) using the method described by Weaver and Fritts (1979). Wolf scats were teased apart in the field between June 1995 and March 1998 and prey were identified and quantified as percent occurrence to determine diet (Thompson 1952).

During the first summer car-killed deer were provided *ad libitum* and inspected frequently to estimate the percent utilization, in kg, by the Wolf. Weights of summer car-killed deer were estimated using regional age-sex averages: fawns, 18 kg; does, 45 kg; bucks, 57 kg. Age-sex specific weights of winter Wolf-killed deer were calculated by assigning age-sex specific mean weights from SWA hunter harvested Deer (W. Hall, unpublished data, WDNR, SWA). Winter consumption rates were determined by following Wolf trails in snow to kill-sites and estimating percent utilization by Wolf 501M and other scavengers. Daily consumption rate was determined by dividing the sum of the calculated weights of deer consumed by the Wolf by the number of days Wolf trails were followed each winter, and the number of days car-killed deer were available in summer 1995 (Kolenosky 1972).

Alpha pack Wolves, and recently formed pairs, raise-leg urinate (RLU) as a means of displaying dominance and marking their territories (Peters and Mech 1975; Rothman and Mech 1979). Lone Wolves that disperse into areas devoid of Wolves and appear to have established territories also RLU (Ream et al. 1985; Thiel, unpublished data). Observations of Wolf 501M's urination types (RLU

vs squat-leg urination [SQU]) were combined during three winters. The presence of RLUs was interpreted as sign that 501M had established a territory in SWA (Peters and Mech 1975; Rothman and Mech 1979).

Results and Discussion

Wolf trails observed between 2 June and 5 August 1995 indicated the Wolf favored its injured limb and used it only when standing, and intermittently while moving. It used its injured limb in each of five trails observed between 21 August and 11 September. Trails followed between mid September 1995 and 10 March 1999 indicate the Wolf consistently favored its right front leg, using it only when chasing Deer or moving up or down steep slopes.

Wolf 501M ate a frozen Beaver carcass placed inside the kennel on the night of his escape. On 26 and 30 May Wolf scats found within SWA contained Beaver hair.

On 2 June 1995, Wolf tracks were followed to a car-killed deer disposal pit closed 11 months earlier. The Wolf exhumed a deer carcass 1m beneath the soil and ate it. Between 5 June and 6 November 1995, 28 fresh car-killed deer (1114 kg) were placed at the pit-site. Wolf 501M consumed an estimated 736 kg from 23 of these deer, or 4.8 kg of meat per day during the 153 day period car-killed deer were provided. In addition, the Wolf killed and entirely consumed a 5 kg fawn on 13 June, demonstrating that it was capable of hunting.

Deer were found in 62 percent of 34 summer Wolf scats, 96 percent of 25 winter scats, and constituted 76 percent of 501M's year-round diet. Beaver and Raccoon were present in 14 of 34 (38 percent) summer scats, and rabbit remains were found in 1 of 25 (4 percent) winter scats. Wolf 501M's diet, based on scat analyses, closely resembles the diet of healthy, wild Wolves living in Wisconsin (Mandernack 1983; Thompson 1952).

Daily consumption rates of the Wolf varied slightly during three winters, ranging from 3.0 to 4.4 kg/day. These rates are comparable to rates of wild Wolves studied in other areas where Deer are the major winter food (Fuller 1989; Keith 1983; Kolenosky 1972; Mech 1970; Mech 1977).

I assumed if Wolf 501M did not leave SWA, it would establish a territory and RLU. Raised-leg urinations from Wolf 501M were originally noted in the first snowfall six months following its escape, in December 1995. Eighty-four percent of Wolf 501M's January urinations were RLUs, averaging 1.9 RLU's/km in 51 km of trailing. Wolf 501M's RLU rates dropped markedly in February; 57 percent were RLUs at 0.4 RLUs/km in 25 km of trailing. A similar decrease in RLUs was noted between January and February from another lone, territorial Wolf monitored in northern Wisconsin in 1982 and 1983 (Thiel, unpublished data). This contrasts with

RLU activity of alpha pack Wolves and newly formed pairs which increases throughout the February breeding season (Peters and Mech 1975; Rothman and Mech 1979).

Between 4 December 1997 and 9 January 1998, two Wolves entered SWA, possibly yearling siblings from a Wolf pack residing immediately outside SWA. In four days of trailing between 9 and 20 January, Wolf 501M and the newly arrived pair were not observed together. In this time the pair made several unsuccessful attempts to dig underneath the SWA perimeter fence. On 20 January, the three Wolves were observed traveling together; Wolf 501M displaying dominance by RLUing. One of the newly arrived Wolves displayed estrus blood in her urine on 20 January 1998. A whelping den used in spring 1998 was discovered in SWA on 7 July 1998. No pups evidently survived, and Wolf 501M was last observed with another Wolf in October 1998. He continued to maintain his territory in SWA through winter 1998–1999.

Under certain circumstances Wolves with limb injuries can survive in the wild (Thiel 1993). Although Wolf 501M never regained total use of his right front leg, he survived a minimum of 4.5 years after his leg injury (he was alive as of 24 September, 1999). Factors that aided this Wolf's survival include: (1) surgical repair of the injured limb, (2) car-killed deer supplied for 6 months following escape, and (3) a "release" site devoid of other Wolves where the risk of further injury or death due to interspecific aggression was absent. This debilitated Wolf demonstrated that it was a capable hunter, remaining adequately nourished. It settled into a territory, associated with other Wolves for greater than 8 months, and maintained his dominance in that time.

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Response of Breeding Male Ruffed Grouse, *Bonasa umbellus*, to Playbacks of Drumming Recordings

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On seven separate occasions I assessed the response of breeding male Ruffed Grouse (*Bonasa umbellus*) to a playback of a drumming recording. On five occasions, the resident male grouse approached to within 20 m of my location, four of these between 9 and 3 m, despite my making no attempt to conceal my presence. This technique may be useful in verifying the presence of breeding males in known territories, and may also be useful in luring breeding males within noosing range for capture.

Key Words: Ruffed Grouse, *Bonasa umbellus*, playbacks, drumming, trapping, census, breeding season, breeding males, territorial, Alberta.

Male Ruffed Grouse (*Bonasa umbellus*) drum from one or several locations (usually logs) within a territory during the spring breeding season (Gullion 1967). Drumming, which produces a sound audible to the human ear up to 300 m away, functions both as a territorial defense mechanism and as a means to attract females (Bump et al. 1947). Because it is relatively easy to detect drumming male grouse, censuses using drumming counts as an index of population size or density are commonplace (Petraborg et al. 1953; Frank 1947). Furthermore, as drumming logs are easy to locate, breeding males may be trapped using mirror traps placed near drumming logs (Gullion 1965). Both the censusing and the trapping methods have drawbacks, however. Gullion (1966) pointed out problems in using drumming counts to estimate population density, due to presence of silent males. Mirror traps, while reasonably effective, are passive sampling, and many trap-days may pass before a targeted individual is trapped. Actively searching out and capturing individual Ruffed Grouse with noosing poles is much more difficult than noosing tamer grouse species such as Spruce Grouse (*Falciennis canadensis*) and Blue Grouse (*Dendragapus obscurus*) (Zwickel and Bendell 1967).

Despite the use of playbacks of territorial songs/calls to census or attract many other bird species (e.g., Falls 1981; Villard et al. 1995; Rail et al. 1997), I could find no mention of use of playbacks of drumming recordings in the Ruffed Grouse literature. Therefore, I made field trials as a preliminary investigation of how breeding male Ruffed Grouse respond to such playbacks.

On 6 and 7 May 1999, I conducted playback trials using a recording of drumming by a male Ruffed Grouse from Peterson Bird Songs, Western Edition. The trials were in the Cooking Lake-Blackfoot Provincial Recreation Area in central Alberta

(53° 26' N, 113° 02' W). I used a portable stereo player (Sharp WQ - CD220) which had an extra bass option to better replicate the low frequencies produced by drumming grouse. The drumming recording was played through an amplified 6 × 9 - inch mid-range speaker (Kudelski S. A., Switzerland), and was clearly audible to human ears at least 150 m away.

One trial was conducted in the evening on 6 May (18:00), the remainder on 7 May throughout the day (10:00–17:00). The procedure for each trial was as follows: I approached a drumming log known to be occupied during the current breeding season until 20 - 40 m distant. In most cases I selected a log to sit on and placed the portable stereo beside me. The speaker was placed on the ground approximately 1 m away from the stereo. The drumming recording consisted of individual drumming bouts alternating with 3 - 4 minutes of silence. I initially played the drumming tape for about 20 minutes; if there was no response during this time I ended the trial. If the resident male responded to the initial playback I continued playing the tape until the end of the trial. I was careful to minimize motion that would scare off an approaching male grouse, but otherwise made no effort to conceal my presence. During a trial I noted general behavioural responses of the resident male grouse to the playback. Trials ended 30 minutes to 1 hour after they began. Each trial involved a different male grouse territory, except trials 3 and 4, which mistakenly involved the same territory. Results of each trial follow:

Trial 1 — I sat on a log 20 m from the resident male's drumming log and played the recording. The male immediately appeared and throughout the course of the trial circled my location at a distance of 6 m, strutting and making aggressive clucking sounds. Eventually, the male climbed onto the log I

was sitting on, about 9 m away, and remained there until I ended the trial after 50 minutes.

Trial 2 — I parked my vehicle on a narrow road and set up the speaker on the hood, 45 m from the resident male's drumming log. I remained in the truck and played the drumming recording. Throughout the 30-minute trial, the male circled the truck at a distance of 9 m while strutting and clucking. The male appeared reluctant to linger on the open road, but crossed it several times. This behaviour continued until the end of the trial.

Trial 3 — I sat on a log 40 m from the resident male's drumming log and played the recording. The male was very aggressive, strutting and clucking, and seemed almost oblivious to my presence, approaching to 3 m from the speaker. It subsequently retreated to approximately 20 m away and remained in the vicinity until the trial ended.

Trial 4 — I inadvertently placed the speaker too close to the territory of the male used in Trial 3, therefore this bird again responded to the drumming playbacks. It approached only to 9 m this time, and was much less aggressive than in Trial 3. It remained at the same distance away from the speaker throughout the trial. This suggests the individual had already become habituated to the playback; habituation has been noted in other bird species subjected to call playbacks (e.g., Searcy et al. 1994).

Trial 5 — I sat on a log 13 m from the resident male's drumming log, and played the drumming recording for 20 minutes. There was no response.

Trial 6 — I sat on a log about 2 m away from a secondary drumming log (Gullion 1967). The resident male was apparently drumming on another log about 40 m away. For the first 20 minutes of the playback, the resident male continued drumming. After 20 minutes, however, the male appeared, approximately 20 m away. This individual was extremely cautious, and approached no closer than 20 m. It did not strut nor make clucking noises. When I ended the trial and approached the bird, it did not flush but rather fled on the ground, as territorial males are inclined to do.

Trial 7 — I sat approximately 5 m from a resident male's drumming log. The male was drumming on another log approximately 30 m distant. The male seemed to drum in response to the playback, as on several consecutive drumming bouts, it drummed immediately after the recorded bout ended. Males drumming in sequence during the breeding season were noted by Archibald (1976). The male had not approached the speaker after 20 minutes, therefore the trial was ended.

These results verify that playbacks of Ruffed Grouse drumming may be useful in censusing. In the one trial where no response from the resident male was elicited, drumming was not heard, nor was the bird seen, prior to the trial. Playback trials were con-

ducted approximately 10 days after estimated peak of drumming activity as judged from the frequency of drumming individuals and weather conditions. Stronger responses might have been observed had the trials been conducted during the peak period.

Playbacks of drumming recordings could also be useful in luring Ruffed Grouse into noosing range for capture. Although generally regarded as a wary bird, Ruffed Grouse responding to the drumming playback approached to within 9 m of my location on four of five occasions. Had I hidden, and had a stuffed dummy grouse been placed near the speaker, grouse might have approached the playback location to within noosing range.

Finally, although the drumming playback appeared of sufficient realism to "fool" male Ruffed Grouse, to the human ear the playback did not fully capture the bass sound of the drumming. I recommend use of a woofer or sub-woofer, rather than a mid-range speaker, when using playbacks of drumming recordings.

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Orphan Caribou, *Rangifer tarandus*, Calves: A Re-Evaluation of Overwinter Survival Data

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Joly, Kyle. 2000. Orphan Caribou, *Rangifer tarandus*, calves: A re-evaluation of overwinter survival data. *Canadian Field-Naturalist* 114(2): 322–323.

Low sample size and high variation within populations reduce power of statistical tests. These aspects of statistical power appear to have affected an analysis comparing overwinter survival rates of non-orphan and orphan Caribou (*Rangifer tarandus*) calves by an earlier study for the Porcupine Caribou Herd. A re-evaluation of the data revealed that conclusions about a lack of significant difference in the overwinter survival rates between orphan and non-orphan calves were premature.

Key Words: Caribou, *Rangifer tarandus*, calf, mortality, sample size, statistical power.

Russell et al. (1991) concluded that Porcupine Caribou Herd Caribou (*Rangifer tarandus*) calves that remained with their mothers throughout the winter did not show “a measurable increase” in overwinter survivorship compared to those that were orphaned. Their data revealed a survivorship ratio of 78.3% (94 of 120) for non-orphans and 62.5% (5 of 8) for orphans — a 15.8% difference. They concluded that there was not a significant (presumably, $p < 0.05$) difference between the overwinter survivorship of non-orphan and orphan calves ($\chi^2 = 0.36$, $df = 1$, $P = 0.54$, Russell et al. 1991). Noting the 15.8% difference between the two groups and the lack of significance using a 2×2 contingency table (Zar 1974), I examined the power of their analysis.

“Power is the probability of obtaining a significant result in a statistical test when the null hypothesis is false and a particular alternative is true” (Bart et al. 1998). Power increases with sample size and when populations are uniform (Bart et al. 1998). Uniformity, in this context, means low variability in overwinter survival rate between individuals or groups within the population. Small sample size and lack of uniform populations compromised the power of the Russell et al. (1991) analysis. A significant difference (at either the 90% or 95% level) between non-orphan and orphan overwinter survival would not be detected unless ≤ 3 (37.5%) of the eight orphans survived until spring ($\chi^2 = 4.77$, $df = 1$, $P = 0.03$). This result was directly attributable to small sample size.

The other aspect of power that affected the strength of the Russell et al. (1991) analysis was the lack of similarity within groups. Kojola (1989) noted differences in feeding behavior between cows with female calves and those with male calves. Calf weight loss and shared use of feeding craters during the winter showed a sexual bias. Male calves spent less time sharing craters with their mother and, correspondingly, weight loss in males was less affected by their mothers' rank than in females (Kojola 1989). The less dependent orphan males might be expected to have a higher overwinter survivorship than females; however, it should be noted that both of the male orphan calves, compared to 1 of 6 (16.7%) females, in the Russell et al. (1991) study did not survive the winter. Sexual bias in overwinter survival of Caribou calves, under starvation conditions, has been reported in other studies (see Skogland 1985; Bergerud and Elliot 1986), with male calves tending to succumb more frequently than females. Another potentially important factor was the age at which calves are orphaned. I predict that calves orphaned later in their life have a greater chance of survival. The data given by Russell et al. (1991) suggests 75% of the calves orphaned in November survived the winter, compared to only 50% of the calves orphaned in September. If possible, survival data should be collected during the same time period to avoid confounding variables such as seasonal or annual differences in weather, predation or forage availability. Given the low power

of the analysis presented by Russell et al. (1991), the possibility of a Type II error (actual differences between the groups goes undetected) appears high.

The use of confidence intervals has been recommended to avoid problems associated with the retrospective use of power analysis and to gauge the robustness and biological relevance of study results (Bart et al. 1998; Gerard et al. 1998). The 95% confidence interval I estimated using Russell et al.'s (1991) data for the overwinter survival rate of orphan calves was extremely wide (29.0% to 96.0%) compared to that of non-orphaned calves (71.0% to 85.7%). A 95% confidence interval for the difference (15.8%) in the overwinter survival rates was -18.5% to 50.2%. This range suggests that orphaned calves could be persisting through winter at a rate anywhere between nearly 20% higher and 50% lower than non-orphaned calves. This range of possibilities should not be considered acceptable because there are obvious biological differences in the confidence interval. In other words, the data presented by Russell et al. (1991) does not unequivocally indicate that the overwinter survival rate of orphan calves was the same as, lower nor higher than non-orphan calves. A 15.8% difference in survival rate may not have been statistically significant, but it may large enough to be important in the biology of this species. Biologists and managers should be interested in biologically, not just statistically, significant differences (Gerard et al. 1998).

Russell et al. (1991) noted that the high energetic cost of cratering (Thing 1977; Fancy and White 1985) and the shared use of craters between a cow and its calf (Shea 1979; Kojola 1989) may contribute to lower overwinter survival of orphaned calves. Orphaned calves are at a disadvantage because they must spend energy digging craters on their own rather than benefiting from the use of their mother's crater. Calves pawed less when they were able to share their mother's crater than when they were separated (Kojola 1989). Furthermore, subordinate Caribou often are forced to forfeit the craters they have dug to dominant members and thus expend even more energy to crater anew (Kojola 1989).

The data presented by Russell et al. (1991) raise interesting questions about the fitness of orphan Caribou calves, such as relative fitness and presence of sexual and/or temporal (date of orphanage) biases in survivorship of orphans. Further research is necessary to answer these questions. Sample size would have to be much larger, presuming a rate of survivorship equal to the one reported by Russell et al. (1991), before a significant difference in overwinter survival rate would be identified. Controlling for

biases would compound the problem of small sample sizes. However, identifying potential biases could reveal simple solutions to seemingly complex problems. For example, further research might reveal an age at which orphans have a high rate of overwinter survival. The lack of robust data should lead to conservative management recommendations. Given the limited power of the Russell et al. (1991) analysis, managers may want to rethink their position on using their conclusions in the estimation of sustainable harvest for the Porcupine Caribou Herd.

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Site Characteristics of a Repetitively Used Harlequin Duck, *Histrionicus histrionicus*, Nest in Northern Labrador

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As part of field investigations for the Voisey's Bay Mine Mill Environmental Assessment in 1995, baseline studies on Harlequin Ducks, *Histrionicus histrionicus*, were initiated around the proposed site on Labrador's north coast. During ground brood surveys in 1997, a Harlequin Duck nest was discovered. This was the second Harlequin Duck nest ever found in Labrador. The exact same site was used again in 1998 indicating favorable nesting habitat and repetitive nest-site use for Harlequin Ducks in Labrador. This finding contributes to our meager knowledge of the species breeding habits in Labrador and has implications on future research.

Key Words: Harlequin Ducks, *Histrionicus histrionicus*, nest, breeding, Labrador.

Harlequin Ducks (*Histrionicus histrionicus*) are relatively small sea ducks that spend the majority of their annual life cycle along rocky intertidal coastal shores, migrating inland during the breeding season (Bengtson 1972; Cassirer and Groves 1991*; Butler 1998; Rodway et al. 1998; Robertson et al. 1998). Although there is contention over historic and current population sizes (Vickery 1988; Goudie 1989; Goudie 1991*), probably due to the lack of structured census information, the eastern North American population was designated as endangered in 1990 and has since gained much attention (COSEWIC 1998*; Montevecchi et al. 1995). The breeding distribution has not been well documented and has also been based on limited information (Goudie 1988; Montevecchi et al. 1995). The majority of information collected on this species in Labrador and northeastern Québec has been through aerial and ground surveys (Goudie et al. 1994; Department of National Defence (DND) unpublished data) conducted at various times of the year. Surveys for Harlequin Ducks in Labrador have increased over the past decade as a result of several environmental assessments for proposed projects (JWEL 1997*). Here we describe a nest site used by Harlequin Ducks in two successive seasons, providing evidence for nest-site fidelity.

Study Area and Methods

The study area was a sheltered north-south oriented valley connecting Anaktalak Bay and Voisey's Bay in northern Labrador. The field study was conducted as part of the Avifauna Technical Data

Report (JWEL 1997*) prepared for Voisey's Bay Nickel Company prior to the proposed development of a nickel, cobalt and copper mine. The surrounding terrain is rugged with elevations ranging to 400 m asl. Land at lower elevations is forested mainly with Black Spruce (*Picea mariana*) with dense shrub-covered stream edges, whereas higher elevations are tundra habitat. The climate is subarctic with short summers and long winters.

In selected areas where breeding pairs of Harlequin Ducks were identified during helicopter surveys in June 1997, ground surveys were conducted in late July to survey for broods. In 1998 and 1999, only ground surveys were employed to search for broods. Ground brood surveys were conducted in selected areas 2 km above and below river sections where pairs of Harlequin Ducks were identified, using two-person teams walking either side of a stream to search for nests and broods.

Results

On 23 July 1997, during brood surveys along Reid Brook (56°23'N, 62°16'W), a female Harlequin Duck was flushed from dense vegetation when approached within 3 m. The female flew downstream and was not observed again that day. A quick search of the area revealed a nest on the ground. The nest was a down-lined cup, containing 4 dull white, unmarked eggs. It was large enough to encompass the four eggs snugly. The eggs were warm to the touch and not covered by down. The nest was revisited on 11 August 1997 and the presence of four intact egg membranes and caps indicated that the entire clutch had hatched successfully.

The ground cover in a 2 m circumference around the nest consisted of thick moss (*Sphagnum* spp.)

*See Documents Cited section.

and Tundra Dwarf Birch (*Betula glandulosa*) leaf litter. The nest was at the base of a clump of four small Black Spruce trees 1 to 2 m tall, < 4 cm in diameter, in a thick patch of tundra dwarf birch and willows (*Salix* spp.) approximately 10×50 m, running parallel to the river. The understory was very dense, with Black Spruce forest on both sides of the river.

The nest was located on the top of the riverbank, which rose abruptly 1.5 m from water level to an elevated plain. The nest was 1 m back from the edge of the bank. The river was boulder strewn and approximately 5 m wide, 0.5 to 1.5 m deep with short riffles and flowed rapidly over a gravel and small boulder bottom. Approximately 200 m downstream was a flat area 200×300 m of Mountain Alder (*Alnus crispa*), willow and grasses. A network of small braided streams flowed through this delta-like area emptying into a long run-like "steady" section in the river.

The nest site was revisited again the following year on 24 July 1998. It contained a Harlequin Duck nest in the identical location, under the same clump of spruce trees, with five white eggs. The nest was covered with down as if the female had prepared the nest prior to departure. The down was wet and matted on top but dry underneath and the eggs were cold, suggesting that it had been some time since the female had abandoned the nest. One egg was removed and broken open, revealing that it was in the early stages of decomposition. The yolk was runny and formless and mixed with the cloudy albumin suggesting the nest had been abandoned shortly after the completion of the clutch. The reason for abandonment was unknown and no sign of disturbance was evident nearby. No Harlequin Ducks were observed within 300 m of the site. The area was searched again on 23 July 1999, but the vegetation had been removed by ice scouring and no nests were found.

Discussion

The ecology of the Harlequin Duck in eastern Canada has been poorly studied despite its designation as an endangered species by COSEWIC. Females typically incubate the clutch of five to six eggs for 28 to 30 days (Bengtson 1972; Palmer 1976). In nests recently discovered in eastern Canada, Rodway et al. (1998) reported a clutch size of six at Hebron in Northern Labrador and Brodeur et al. (1998) had two nests containing at least four eggs each and one with seven eggs in the Forillon National Park, Gaspé Peninsula, Québec. The first nest discovered in Newfoundland was located on a cliff near the Torrent River in 1999 (R. I. Goudie, personal communication).

Harlequin Ducks appear to have high site-fidelity to breeding areas in Labrador (DND unpublished data; JWEL 1997*), as individuals are seen on the

same sections of rivers each year. In Oregon, Bruner (1997) recorded evidence of nest-bowl reuse in consecutive years in 8 of 20 Harlequin Duck nests and one case of a female using the same nest for both years of the study.

This is the second nest identified and the first documentation of repetitive use of a nest site in Labrador. Nest site locations have been identified in other regions in eastern Canada (Brodeur et al. 1998), but none have recorded repetitive nest-use. Our nest site was close to a section of braided river with several channels and islands followed by a relatively calm section of river used possibly as brood-rearing habitat. The nest site was similar to that described by Rodway et al. (1998), which was located on an island densely covered with willow and alder shrubs and ground cover of moss, herbaceous vegetation or bare ground. Although nest sites may vary, both nests found in Labrador were near rivers with small islands. In a telemetry study in Oregon, Bruner (1997) located five of twenty nests on islands of which three were on the ground and two were on elevated structures.

Breeding records (broods) have only been confirmed along the coastal river systems of northeastern Labrador (Goudie et al. 1994; Rodway et al. 1998), rivers flowing into the Churchill River in central Labrador (DND unpublished data), northwestern Québec (G.R.E.B.E. 1993*) and southeastern Québec (Brodeur 1998, 1999). Typically, these broods have been located on relatively narrow (< 150 m wide) and shallow (1 to 3 m deep) rivers with a series of frequent rapids and large pools. The location of broods is probably not a good indicator of favorable nesting habitat as broods may move considerable distances (up to 30 km) during brood rearing (Bruner 1997). In addition, some females observed on rivers in July do not have broods, and probably represent immature birds and non-breeding adults (Bengtson 1972). With these recent ground brood surveys, we are beginning to understand the relationship of spring breeding pair locations and actual breeding habitat.

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Predation on an Eastern Chipmunk, *Tamias striatus*, by an American Crow, *Corvus brachyrhynchos*

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Nocera, Joseph J. 2000. Predation on an Eastern Chipmunk, *Tamias striatus*, by an American Crow, *Corvus brachyrhynchos*. *Canadian Field-Naturalist* 114(2): 326–327.

An individual adult Eastern Chipmunk, *Tamias striatus*, was observed to be captured and devoured by an American Crow (*Corvus brachyrhynchos*). This is the first report of an American Crow preying upon an apparently healthy adult Eastern Chipmunk, or any small mammal of similar size.

Key Words: Eastern Chipmunk, *Tamias striatus*, American Crow, *Corvus brachyrhynchos*, predation, Maine.

The American Crow (*Corvus brachyrhynchos*) is a common omnivorous scavenger with a continent-wide distribution (Bent 1946). Their typical preferred habitats are partly wooded areas and edges (DeGraaf and Rudis 1987), but they are also often

associated with urban areas (Ward and Low 1997) and are well known consumers of carrion, insects, bird eggs and nestlings, fruit, grain, etc. (Bent 1946; Palmer 1949). Hitherto, crows were not known predators of larger small rodents, such as the Eastern

Chipmunk (*Tamias striatus*), which share the easterly population distribution of the crow and favor the same habitat types (DeGraaf and Rudis 1987).

The following incident was observed on the campus of Colby College, Waterville, Maine, USA (69° 38' W, 44°33' N) on 12 June 1999, 17:50–18:00h. I noticed an Eastern Chipmunk at a distance of 20 m from me, scurrying outside a garbage container near the entrance to a dining hall. Within ten seconds of my noticing the animal, a crow flew down and landed on top of the container, at which point the chipmunk darted under the canopy of a shrub one meter away. The crow, noticing the rodent, alighted on the ground near the chipmunk's position, causing it to scurry to a second shrub one meter away. Whether the crow was initially attracted to the garbage present in the container or the activity of the chipmunk is unknown. The crow then hopped along the ground apparently chasing the chipmunk, at which point it began running from shrub to shrub. In all, this chase lasted approximately one minute, ending when the crow managed to grab the chipmunk with its beak at the base of the neck. When it had the chipmunk firmly grasped, it shook the prey, presumably breaking its neck, thus ending the struggle.

The crow then flew with the chipmunk in its beak to a dense tree canopy nearby, landed on a branch approximately ten meters off the ground, and proceeded to tear at the chipmunk grasped in its perched feet. By approximately seven minutes post-capture, the chipmunk was completely devoured. After con-

suming its prey, the crow then flew 400 m west to join a group of crows congregated there, at which point I lost track of the individual.

To my knowledge, this is the first report of an American Crow preying upon an Eastern Chipmunk or any seemingly healthy small mammal of the same size which may indicate that crows are a greater threat to larger small mammals than previously realized. However, as the typical incubation period for crows in the northeast was near its end when this event occurred (DeGraaf and Rudis 1987), there were likely young chicks to feed, and the pressure placed upon the adult to provide for itself and its young may have offered significant impetus to attempt capture of prey of this size and speed.

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A Large Mid-winter Observation of Bonaparte's Gulls, *Larus philadelphia*, in Head Harbour Passage, New Brunswick

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Huettmann, Falk, Ken MacIntosh, Cam Stevens, Tracey Dean, and Antony W. Diamond. 2000. A large mid-winter observation of Bonaparte's Gulls, *Larus philadelphia*, in Head Harbour Passage, New Brunswick. Canadian Field-Naturalist 114(2): 327–330.

We observed 6030 Bonaparte's Gulls (*Larus philadelphia*) near Head Harbour Passage in eastern Passamaquoddy Bay during boat surveys for wintering Razorbills (*Alca torda*), 30 December 1998. A second survey on 27 January 1999 found no Bonaparte's Gulls. Our observations are the highest counts of this species in eastern Canada in late December; implications of these findings are discussed in the context of existing knowledge of migration in this species.

Key Words: Bonaparte's Gull, *Larus philadelphia*, fall migration, Head Harbour Passage, Passamaquoddy Bay, lower Bay of Fundy, New Brunswick.

The eastern population of Bonaparte's Gull (*Larus philadelphia*) is known to use Passamaquoddy Bay in southwestern New Brunswick from August to December as a resting and moulting area

during fall migration (Braune 1987a, 1989). During a study of wintering Razorbills (*Alca torda*) (Huettmann unpublished data; Huettmann and Diamond 1999*) we made two surveys, starting and ending at

the Letete ferry wharf, of Head Harbour Passage on 30 December 1998 and 27 January 1999, with the University of New Brunswick research vessel Mary O (Figure 1). Each survey began at 09:30 and lasted for 2 hours 10 minutes. Ship speed was approximately 6 knots; bird counts were by naked eye extending 360° around the vessel, using binoculars for species confirmation. The first survey (by F. H.) revealed 6030 Bonaparte's Gulls, which we consider an underestimate due to bad weather (rain and dense snow) during the first hour of the survey.

Most of the gulls were in two distinct flocks (Figure 1), both surface-feeding on the well-known eddies and gyres; one, of about 1500 birds between Wilson's Beach and East Quoddy Head, and the other, of about 4400 birds south of Deer Island (Deer Island Point). In addition, 130 individuals were travelling in small groups towards or from these two flocks. Birds were not specifically scanned for age classes, but only adult birds were seen. Besides small numbers of other waterbirds, 3202 Black-legged Kittiwakes (*Rissa tridactyla*)

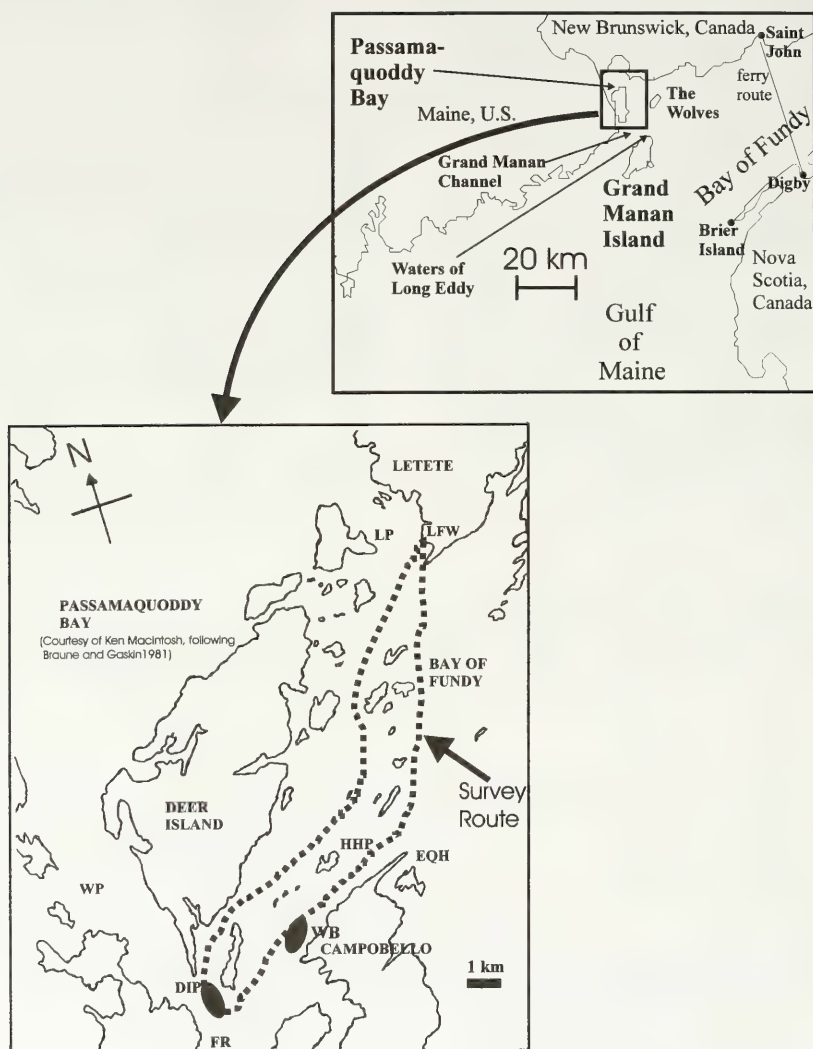


FIGURE 1. Map showing the study area of Head Harbour Passage around Deer Island, the vessel survey route and locations referred to in the text. Locations of Bonaparte's Gull sightings during surveys are shown as black ovals. Abbreviations: DIP = Deer Island Point, EQH = East Quoddy Head, FR = Friar Roads, HHP = Head Harbour Passage, LP = Letete Passage, LFW = Letete Ferry Wharf (Start and End of Survey), WB = Wilson's Beach, WP = Western Passage.

were also counted, mostly at the same two locations, but not in such dense flocks as the Bonaparte's Gulls. Species identification of these two similar species was easy as the birds could be approached as close as 15 m.

The second survey (by F. H. and T. D.) used the same route but under optimal weather conditions (no wind, no precipitation, sunny, freezing temperatures); no Bonaparte's Gulls and one Black-legged Kittiwake were counted.

Eighteen surveys of the Head Harbour Passage had been carried out earlier from land by K. M. from 21 July to 12 September 1998 to compare the timing and numbers of migrating Bonaparte's Gulls with earlier work by Braune (1989). He counted at high tides for approximately 3 hours and his highest estimate was 3500 individual Bonaparte's Gulls off Deer Island Point on 12 September (MacIntosh 1999). Timing of this peak matches with findings by Braune (1989).

Braune (1987a, 1989) described Passamaquoddy Bay as the only known major moulting and staging ground of Bonaparte's Gulls in eastern Canada during fall migration (see also Godfrey 1986). The birds arrive on their wintering grounds in southern U.S. and Gulf of Mexico region from November on (Braune 1989). The first wave of birds at Passamaquoddy Bay peaked in July–September, with a high percentage of juveniles; second and third smaller peaks, consisting mostly of adult birds, were found in October–December (Braune 1987a). The third wave at Passamaquoddy Bay coincided with the major wave of migration in the Great Lakes, and was hypothesized to be dominated by western Canadian birds. This migration pattern matches the timing of surface swarming of euphausiids in the Passamaquoddy Bay (Braune 1987b).

Braune (1989) estimated that approximately 21 % of the North American population migrates along the Atlantic flyway, with peak numbers of 5000–10000 birds in August in Passamaquoddy Bay. She found that almost all birds had left the area by November, with very few individuals up to 31 December, and no birds in March. Our finding of large numbers of birds in late December contradicts this pattern. Although our counting methods are not directly comparable with those of K. M. and Braune (1989), our 30 December count was still unexpectedly high. The Bonaparte's Gulls observed during our survey of 30 December were easy to count because most were in two large flocks at least 1 km apart, so we are confident that our numbers do not include double counts. We were not able to check the main part of Passamaquoddy Bay during our surveys but only the southeastern entrance, Head Harbour Passage (Figure 1), and it is possible that more birds were present in the larger "Quoddy" region (including Passama-

quoddy Bay and extending out to Grand Manan and the Wolves archipelago; Figure 1, Huettmann unpublished data). We did not observe other late migrants relevant to our observation. During two years of ferry surveys between Saint John, New Brunswick–Digby, Nova Scotia, F. H. did not find significant numbers of Bonaparte's Gulls in the upper Bay of Fundy (Huettmann and Diamond 1998*; J. Nocera personal communication for Brier Island) and a maximum of only 400 birds at Digby Neck during fall (also K. Allard, personal communication). This might well indicate that the western Bay of Fundy offers a unique habitat for Bonaparte's Gulls. Our high numbers in late December coincide with counts of up to 3000 Bonaparte's Gulls during the same time (December 1998) on land- and vessel-based surveys for wintering Razorbills off northern Grand Manan and the Wolves archipelago (Huettmann and Diamond 1999*; F. Huettmann and C. Stevens unpublished data). We also observed several smaller flocks of Bonaparte's Gulls in the Grand Manan Channel, apparently traveling between northern Grand Manan Island, the Wolves, and Passamaquoddy Bay. Although we have no numbers or surveys for this area from previous years the findings from December 1998 indicate that both areas need to be taken into account for future work on this species during fall migration and early winter. We saw no Bonaparte's Gulls in these regions on our surveys after December.

At present, we can only speculate if our findings of high numbers in December are unusual or a regular event, but Braune (1987a) and some Christmas Bird Counts for the Passamaquoddy Bay area suggest that very few Bonaparte's Gulls are usually found in the area during late December. Other reasons for our high count so late during the year could include: large-scale weather-related migration factors; another overlooked migration wave of Bonaparte's Gulls through this staging area; increase of a particular subpopulation; decrease in attractiveness of the Great Lakes area as a staging ground; or, an increase in attractiveness of the Quoddy region, perhaps because of delayed surface swarming of euphausiids (Braune 1987a, 1987b, 1989) caused by so far unknown reasons. We have no indication linking our finding directly to any offshore fishery related activities, nor do we have long-term sea surface temperatures for the area. Weather data for the area do indicate for December a monthly mean air temperature below 0°C, which is normal for this time of the year (based on monthly mean air temperatures 1976–1998 for the area).

There are some possible reasons why there is a general lack of knowledge of Bonaparte's Gulls in this region. First of all, in winter Black-legged Kittiwakes can easily be confused by untrained observers with Bonaparte's Gulls; at this time of the year most small white gulls in the Bay of Fundy

either are not observed carefully enough, or are hard to identify from a distance. Secondly, the Quoddy Region is difficult to access and lies on the Eastern Canadian-U.S. border so that information on bird sightings is not readily exchanged, and therefore these border-crossing birds are easily ignored. Thus, consistent and well-designed international investigations using both vessel and land-based surveys, are needed to resolve details of Bonaparte's Gull migration.

Acknowledgments

We thank the ACWERN team, CWS (Canadian Wildlife Service), Bruce MacDonald and Captain Bob Bossein (University of New Brunswick, St. John) for supporting our boat surveys. We also thank Karel Allard, Joe Nocera and Richard Stern for sharing their knowledge about Bonaparte's Gulls. William Richards, Environment Canada Fredericton, kindly provided long-term weather data for Seal Cove and Pennfield. This is ACWERN publication number UNB-12.

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New Yellow Rail, *Coturnicops noveboracensis*, Site in Atlantic Canada

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Kehoe, F. Patrick, Lee A. Swanson, Graham J. Forbes, Susan Bowes, and Peter A. Pearce. 2000. New Yellow Rail, *Coturnicops noveboracensis*, site in Atlantic Canada. *Canadian Field-Naturalist* 114(2): 331–332.

We document the presence of the largest known concentration of Yellow Rails (*Coturnicops noveboracensis*) east of Quebec, in the Grand Lake Meadows of central New Brunswick. Rails were surveyed between 1991–1997 and indicated the area supported a minimum of 2–24. Fluctuating water levels appear to determine abundance and suggest that breeding is unlikely, at least in most years. The Grand Lake Meadows may be a significant post-breeding staging area for this species.

Key Words: Yellow Rail, *Coturnicops noveboracensis*, distribution, habitat, New Brunswick.

The Yellow Rail (*Coturnicops noveboracensis*) is a poorly understood wetland bird species requiring specialised breeding habitat, mainly floating and partially submerged senescent sedge (*Carex* spp.) mats in freshwater marshes (Bookhout and Stenzel 1987). The known distribution of the northern subspecies (*C. n. noveboracensis*) suggests a very sporadic, discontinuous pattern of fewer than fifteen colonies identified in wetlands across boreal, sub-arctic, broad-leaved and prairie regions of central North America (Bookhout 1995). In the Maritimes region of Canada (New Brunswick, Prince Edward Island, Nova Scotia) Yellow Rails are considered very rare; only three sites were recorded, and no breeding confirmed, during the five-year Maritimes Breeding Bird Atlas project (Erskine 1992). A single breeding record in southern New Brunswick was obtained in 1881 (Chamberlain 1882), and rare sightings of individuals, or of several birds, most notably near Sackville, New Brunswick, were made since 1949 (Squires 1976), and central Maine in 1990 (Gibbs et al. 1991). This note presents the results of seven years of surveys in the only known concentration where systematic surveys have been made in the Canadian Maritimes or on the American eastern seaboard.

Two male Yellow Rails were incidentally recorded during waterfowl banding operations during the first week of August 1987 at Grand Lake Meadows (45° 51' N, 66° 12' W), a 4900 ha (49 km²) tide-influenced wetland complex of the St. John River in central New Brunswick. The section containing the Yellow Rails is a 5 km long, 400 ha stretch of emergent marsh dominated by sedges (*Carex lacustris*, *C. lanuginosa*, and *C. lasiocarpa*), as well as Water Horsetail (*Equisetum fluviatile*), Spike-Rush

(*Eleocharis palustris*), Marsh Speedwell (*Veronica scutellata*), Arrowhead (*Sagittaria* spp.), Blue Flag Iris (*Iris versicolor*), Sweet-Gale (*Myrica gale*), Cattail (*Typha latifolia*), Buckbean (*Menyanthes trifoliata*), and Bog Willow (*Salix pedicellaris*) (Roberts 1992).

The site was surveyed specifically for Yellow Rails in 1991–1997. Surveys were conducted as soon as spring flood levels exposed the floating senescent vegetative mat used by rails. Point-count surveys, every 350–400 m along 5 km of marsh shoreline, were conducted from a boat between dusk and 1–2 am, during three to four calm, rainless nights from mid-June to early August. The following minimum numbers of birds were recorded: 1991 (20 birds); 1992 (15); 1993 (15); 1994 (10); 1995 (24); 1996 (3); 1997 (2). We surveyed the entire site each night to avoid double-counting moving birds. Except for two solitary birds found 3 km and 8 km away in 1995, all birds were recorded in the same area of the marsh along a 300 m wide, 5 km length of shoreline southern end of Grand Lake.

We found that rails and available habitat were more abundant when water levels were low. The size and location of the main site varied annually depending on the amount of habitat covered by water during our surveys. The area containing calling males was 50 ha in 1994 when water levels were 16% above the 15-year June monthly mean water level. In 1992, 1993 and 1995, water levels were 10–21% below the 15-year mean and the exposed area with rails was approximately 130 ha in size. Fifteen to twenty-four rails were recorded when water levels were below the long-term average compared to 2–10 rails when levels were above average water levels.

Breeding status was not confirmed during the surveys. We suspect breeding does not occur regularly because birds can not use the site until water levels subside, typically in June, 1.5 months into the species' nesting season. Yellow Rails construct nests in May and incubate eggs for 17–18 days from late May to July, depending on geographic location (Elliot and Morrison 1979; Bookhout 1995). From April to mid-June, much of the wetland in our area is subject to melt-water flooding from the St. John River and the habitat is submerged.

Periodic floods and extended high water levels occurred in three of seven years surveyed. The most dramatic event was in 1996, an above-average flood year (37% above average) when three Rails were recorded. A few days later a severe rain storm, in conjunction with flood controls on a hydroelectric dam upriver, submerged the entire remaining *Carex*-dominated area of the wetland for two weeks in early July. The surrounding area was dry and treed, habitat which rails are not known to use. No rails were heard again that year.

We do not know the exact arrival date of rails to the site because water always covered much of the rail habitat until early June. Rails were heard on the first visit of each year, the earliest recorded on 11 June, and were last heard calling at the end of July. We surveyed after the vegetative mat was exposed and suspect that the birds had recently arrived because the meadows are surrounded by forest and unlikely to support rails. It is possible that the Yellow Rails at Grand Lake Meadows are non-breeders or post-breeders undergoing molt.

Post-breeding movement from other sites also is plausible. In an intensive study along the St. Lawrence River, southern Quebec, five male Yellow Rails, leg-banded during the May–June breeding period, were recaptured approximately one month later from between 50 to 400 km from their original location (Robert and Laporte 1999). Males appeared to have bred in one site, then travelled to other sites and continued to call. In our study, birds typically are not on site until late in the breeding season; males heard in our surveys from 11 June onwards may be non-breeding or post-breeding males. The Quebec sites are the closest known breeding colony and are approximately 350 km from Grand Lake.

The Grand Lake site is similar in population size to several known breeding colonies (Robert and Alvo 1998) and, if supporting breeding birds, would

be the largest and only consistently active site for Yellow Rails known east of Quebec. If birds were not breeding, the site still would be significant as the only known post-breeding staging site in the region.

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Three Records of the Chestnut Lamprey, *Ichthyomyzon castaneus*, New to Québec

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Renaud, Claude B., and Naomi de Ville. 2000. Three records of the Chestnut Lamprey, *Ichthyomyzon castaneus*, new to Québec. *Canadian Field-Naturalist* 114(2): 333–335.

We report on the presence of the parasitic Chestnut Lamprey, *Ichthyomyzon castaneus*, in Québec based on three specimens from three localities spanning a distance of over 400 km.

Key Words: Chestnut Lamprey, *Ichthyomyzon castaneus*, Petromyzontidae, distribution, Québec.

Renaud et al. (1996) reported on the widespread but rare occurrence of the Chestnut Lamprey, *Ichthyomyzon castaneus*, in the province of Ontario. Given the fact that some of the Chestnut Lamprey from Ontario had been misidentified as the more common Silver Lamprey, *Ichthyomyzon unicuspis*, a complete check of the extensive collections of the latter species from the province of Québec, housed at the Canadian Museum of Nature (CMN), needed to be undertaken.

We have relied on a single tooth character to separate the Chestnut and Silver lampreys. Additionally, the number of trunk myomeres was determined following Hubbs and Trautman (1937). Tooth nomen-

clature follows Vladykov and Follett (1967) and Hubbs and Potter (1971). According to Hubbs and Trautman (1937), the two parasitic species are distinguishable from each other by the number of bicuspid circummorals (Figure 1) they possess. The Silver Lamprey possesses 0–2 bicuspid circummorals (mean: 0.03, mode: 0), whereas the Chestnut Lamprey possesses 1–10 bicuspid circummorals (mean: 6.55, mode: 6). The degree of overlap between the two species for this character is 0.6% or 2 out of 342 specimens (Hubbs and Trautman 1937) and hence, is a good diagnostic character. Starrett et al. (1960) and Cochran and Marks (1995) confirmed the fact that Silver Lamprey only rarely possess either one or two bicuspid circummorals; 2 out of 313 specimens in the former and 2 of 414 in the latter study. However, the other diagnostic characters reported by Hubbs and Trautman (1937) to be of lesser value (i.e., number of anterior and lateral rows) were found to have low discriminatory power in the Ontario study (Renaud et al. 1996) and hence were not studied here. When comparing the various species of *Ichthyomyzon*, Vladykov (1949) and Lantaigne (1981) considered the condition, whether bicuspid or not, of endolaterals only, instead of all circummorals. Even so, Lantaigne (1981) obtained good separation between the Silver and Chestnut lampreys, with only 1.3% overlap or one out of 79 specimens. We have followed Vladykov's (1949) and Lantaigne's (1981) less laborious approach when comparing the two species. This means that, if anything, we have underestimated the number of bicuspid teeth present in any given specimen, and therefore, have reduced the likelihood of turning up specimens of Chestnut Lamprey. Note, however, that, according to Hubbs and Trautman (1937: 32), the occurrence of one or two bicuspid circummorals, outside the lateral teeth, is rare.

The examination of 175 transformed lamprey specimens from the province of Québec and held at the Canadian Museum of Nature (CMN; acronym for pre-1995 collections NMC) [87 collections, made between 1941 and 1999, at 29 localities from (west to east) Brewery (Brasserie) Creek, Ottawa

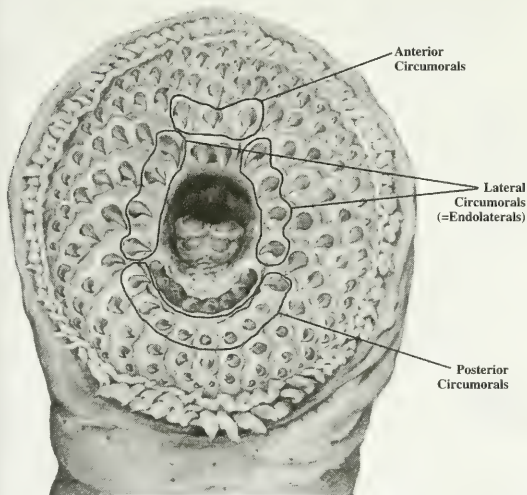


FIGURE 1. Oral disc of a Silver Lamprey. The circummorals, as defined by Hubbs and Potter (1971), are labeled. The lateral circummorals correspond to the endolaterals of Vladykov and Follett (1967). Note the absence of bicuspid endolaterals. Modified from Vladykov and Kott (1980) with permission from the Canadian Journal of Fisheries and Aquatic Sciences.

TABLE 1. Number of bicuspid endolaterals in lampreys of the genus *Ichthyomyzon* from the province of Québec.

Species	0	1	2	3	4	5	6	N	X
<i>Ichthyomyzon unicuspis</i>	156	15	1	—	—	—	—	172	0.1
<i>Ichthyomyzon castaneus</i>	—	—	—	2	—	—	1	3	4.0

(Outaouais) River, Gatineau River, Lake St-François, Lake des Deux Montagnes, Lake St-Louis, Richelieu River, Lake Champlain, St-François River, Lake St-Pierre, St. Lawrence (St-Laurent) River and Ouelle River], revealed that three of these were identifiable as Chestnut Lamprey (Figure 2), and the rest, were Silver Lamprey (Table 1). The first specimen of Chestnut Lamprey was collected on a White Sucker, *Catostomus commersoni*, south of the Island of Montreal, in the area between Dorval (45°26'N 73°45'W in Lake St-Louis) and Grand Chenal (45°40'N 73°28'W in the St. Lawrence River) on 4 November 1941 (NMC86-993). It is a female, 223.5 mm total length and possesses three bicuspid endolaterals and 52 trunk myomeres. This specimen was one of 95 we examined, which were part of the 535 transformed specimens identified by Vladikov (1952: Table 4) as Silver Lamprey from Québec. A second specimen was collected either on a Lake Sturgeon, *Acipenser fulvescens*, or a Northern Pike, *Esox lucius* (the collection data do not specify which), in Brewery Creek (45°27'N 75°42'W), a tributary to the Ottawa River, Hull, on 24 June 1976 (NMC82-147). It is a male, 240.5 mm total length

and possesses six bicuspid endolaterals and 54 trunk myomeres. This specimen was one of 15 we examined, which were part of the 17 transformed specimens identified by Lanteigne (1981: 131) as Silver Lamprey from Québec. Mixing of jars was ruled out as a possible explanation because both the Vladikov and Lanteigne specimens bear tags attached to their bodies, making their recognition unequivocal. Finally, a third specimen was collected in the St. Lawrence River at St-Vallier (46°53'N 70°49'W) on 12 June 1964 (NMC86-986). It is an immature transformed individual, 110 mm total length, with three bicuspid endolaterals and 50 trunk myomeres. This collection also contained a transformed Silver Lamprey. The range in the number of trunk myomeres in the three Chestnut Lamprey from Québec is 50–54. According to Hubbs and Trautman (1937), these numbers could apply to either the Silver Lamprey (47–55) or the Chestnut Lamprey (49–56), although their mean (52.0) agrees more with the Chestnut Lamprey (52.6) than with the Silver Lamprey (50.5).

At the time Vladikov and Roy (1948) and Vladikov (1952) wrote their papers, the closest

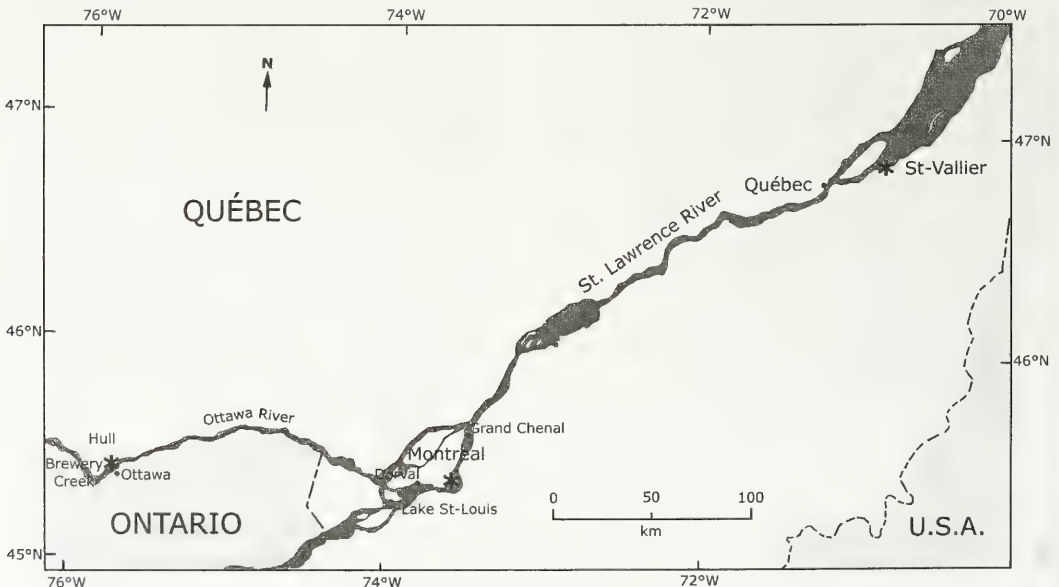


FIGURE 2. Distribution map of Chestnut Lamprey records (*) in the province of Québec.

record of the Chestnut Lamprey to Québec was in the state of Michigan (Hubbs and Trautman 1937) and we submit that Vladykov was not prepared to accept the occurrence of the Chestnut Lamprey in Québec because of the absence of records in the intervening zone. Accordingly, Vladykov and Roy (1948) identified specimens with 3–5 bicuspid circumorals as Silver Lamprey, despite Hubbs and Trautman's (1937) study indicating that a range of only 0–2 occurred in this species. Vladykov and Roy (1948) stated that they studied 409 specimens and that the number of bicuspid circumorals in these varied between 0 and 5, with a mean of 0.08. They did not provide individual counts but in the Vladykov archives at the CMN we found a table dated 8 April 1953 giving counts of bicuspid circumorals for 405 specimens of Silver Lamprey from Québec as follows: 0 (383), 1 (15), 2 (3), 3 (3), 4 (0), 5 (1). Given that we were able to find a single Chestnut Lamprey only (NMC86-993) in the Vladykov material available to us, these data would indicate that the remaining Vladykov material contained three other Chestnut Lamprey, two with a count of three and one with a count of five bicuspid circumorals. These have so far not been found at the CMN. However, if they do turn up, they would not substantively increase our knowledge on the distribution of the Chestnut Lamprey within Québec waters because the records reported here almost fully encompass the distribution for *Ichthyomyzon* in Vladykov (1952). Since the report on the presence of the Chestnut Lamprey in Ontario (Renaud et al. 1996), the geographical gap between Michigan and Québec has been bridged and the presence of the Chestnut Lamprey in Québec is now defensible.

The presence of the Chestnut Lamprey in the province of Québec means that this species is now found in four contiguous Canadian provinces, Saskatchewan, Manitoba, Ontario and Québec. Renaud et al. (1996) reported that the relative abundance of the Chestnut Lamprey and Silver Lamprey in Ontario was 1:47. Based on the Québec material reported here, the ratio for Québec is similar at 1:57. It appears therefore that in both absolute and relative numbers, the Chestnut Lamprey is extremely rare compared to the Silver Lamprey in both provinces. Except for one recent record from Ontario in 1994 (Renaud et al. 1996), the much extended Canadian geographical distribution for the Chestnut Lamprey since Lanteigne (1992), is based on a few historical records (1941–1976) from the provinces of Ontario

and Québec and not on a recent expansion of the range. Therefore, we believe that the status of vulnerable attributed in 1991 to the Chestnut Lamprey by the Committee on the Status of Endangered Wildlife in Canada (Lanteigne 1992) is still appropriate.

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News and Comment

Notices

Ninth North American Caribou Workshop

The Hunting, Fishing and Trapping Coordinating Committee (HFTCC) will host the Ninth North American Caribou Workshop now scheduled to be held 23-27 April 2001 in Kuujuaq, Quebec. The HFTCC was chosen to undertake preparation of this workshop because of its participation in management decisions concerning the caribou herds of northern Quebec and because it has representatives from three native groups. A principal concern is the current state of caribou populations and their future. The Northern Quebec caribou herd comprises the largest population of

free-ranging ungulates in the world. A growing interest in traditional knowledge and the effects of direct and indirect human intervention led to the choice "caribou and man" as the theme of this workshop.

For more information contact Yves Savard-Desilets, Chairman of the Organizing Committee, Workshop Secretariat, Gestion d'événements O'Donoghue et ass., 5486, chemin de la cote Saint-Luc, Montreal, Quebec H3X 2C7; e-mail: nacw@odon.ca; web site: www.cccpp-hftcc.com/nacw.

Ontario Natural Heritage Information Centre Newsletter 5(2)

The Fall-Winter 1999 issue is 20 pages and contains: SCIENCE: Status of Tiger Beetles in Ontario; Belmont Lake Inventory; Life Science Inventory Work on Rainy River and Rainy Lake; Carolinian Canada "Big Picture" update; IBP Catalogue and NHIC Data Accession; NHIC/NRVIS Wetland Project; COMMUNITY ECOLOGY: Rare Communities of Ontario Update; Community-based Biodiversity Conservation in the Western Lake Superior Basin; BOTANY: 1999 Botanical Highlights; Long Point Rare Plant Inventory; Status of Pre-European Settlement Vegetation Mapping; NHIC Herbarium Expands; Marcy Woods Botanical Inventory; HERPETOLOGY: National Ranking of Amphibians and Reptiles; Ontario Hosts Salamander Monitoring

Workshop; ZOOLOGY: Zoology Database Update; First Annual Odonata Summary; NEWS AND NOTES: CCEA Ecogifts 2000 Conference; COSEWIC Adds to the List of Canadian Species at Risk; Ontario's Great Lakes Coastal Wetlands; NHIC to assist with "General Status of Ontario Wildlife" Report; NHIC and Ontario Parks Collaborate on Project in Site Region 7; PUBLICATIONS; NHIC INFORMATION PRODUCTS; NHIC STAFF LIST.

The Ontario Natural Heritage Information Centre Web Page is: <http://www.mnr.gov.on.ca/MNR/nhic/nhic.html>. Mailing address: 300 Water Street, 2nd Floor, North Tower, P.O. Box 7000, Peterborough, Ontario K9J 8M5, Canada.

Sea Wind: Bulletin of Ocean Voice International 13(4)

The October-December 1999 issue, 36 pages, contains: The Eco-Dredge: Evaluation & improvement of shellfish dredge design & fishing effort re conservation measures & environmental impact; A tale of two whales; Project Seahorse; Project Seahorse Survey Request; Thanks to Ocean Voice supporters; Quotes; Ghost fishing gear retrieved: Conservationists search Atlantic for lost fishing gear; 1st International Symposium on Deep Sea Corals: Science & conservation of deep sea corals; Sea News; On

the net; Book Nooke; Ocean Voice International financial statements for 1998; Ocean Voice project report; Ten basic human rights; Ocean Voice International membership form.

Sea Wind is edited by Donald E. Mcallister (e-mail: mcall@superaje.com) and is available through subscription or membership from Voice International Inc., 2255 Carling Avenue, Suite 400, Ottawa, Ontario K2B 1A6, Canada; e-mail: covi@cyberus.ca; World-Wide Web site: <http://www.ovi.ca>.

***Biodiversity: Journal of Life on Earth* 1(1)**

A new journal has appeared to fill niche vacated since the extinction of *Global Biodiversity* (formerly *Canadian Biodiversity*) which had been published by the Canadian Museum of Nature for 8 volumes (see *Canadian Field-Naturalist* 113(2): 311-312). Volume 1, number 1, January 2000 contains: A Contribution to Biodiversity Studies (P. T. Dang); Transgenic Potatoes - Implications of Inserting Bacterial Genes in a Potato's DNA (Brewster Kneen); Diversity in Hybrid Corn Plantings; Ten Principles of Biodiversity for Canadian Agriculture (Ernst Small); Using and Conserving Biodiversity in Calakmul (Julia Murphy); Long-distance Fencepost Sandpipers (Frederick W. Schueler); Orchestrating Bee Genes - A Case for the Precautionary Principle in Genetic Manipulation; In Favour of the Technology Protection

System (TPS) (Harry B. Collins); Biodiversity Awareness - People, Museums and the Web (Don E. McAllister); Editor's Corner (Options in agriculture); Species by Species (Coffee. *Coffea arabica*); News Digest; Book Reviews; Announcements.

The new *Biodiversity* published by the Tropical Conservancy, 94 Four Seasons Drive, Ottawa, Ontario K2E 7S1, Canada. The Editor-in-Chief is D. E. McAllister, and the managing editor is Catherine Ripley. Subscription rates for a year (4 issues) are individuals \$25 and institutions \$50. Canadian orders should add 7% GST, foreign orders should be paid in U.S. funds. Special rates are available for developing countries. Additional information on the journal is available at the web site: <http://www.synapse.net/~tropical/publication.htm>.

***Amphipacifica* Reborn**

The research journal *Amphipacifica* is renewing publication of large monographic studies on the systematics of aquatic organisms. The journal was discontinued in May, 1997, but will soon recommence production with Volume II, Number 4, based in Ottawa, Ontario, Canada. The revised format will be similar to that of the Canadian Journal of Fisheries and Aquatic Sciences and will be under the technical editorship of Dr. David G. Cook, former editor of that journal.

Subscriptions (4 numbers per volume) are renewable at \$50 (Can) or \$40 (US) including surface postage. Author charges are initially \$25. (US) per printed page, subject to change. For further information please contact Dr. E. L. Bousfield, Managing Editor, 1710-1275 Richmond Road, Ottawa, Ontario, Canada K2B 8E3; e-mail: elbousf@magma.ca

***Froglog*: Newsletter of the Declining Amphibian Populations Task Force (37 and 38)**

Number 37, February 2000 contains: Amphibian Declines in Latin America: Workshops to Design a Monitoring Protocol and Database (Karen Lips, Bruce Young, Jamie Reaser, Roberto Ibanez, Antonio Selas); What is PARC and Why Should You Care? (Whit Gibbons); Threatened Amphibians in Cuba (Ariel Rodriguez Gomez and Roberto Alonso); Froglog Shorts; Publications of Interest; Available from the DAPTF [bumper stickers, window stickers, sew-on patches].

Number 38, April 2000 contains: Amphibian uses in Vietnam (Nguyen Quang Truong); The Jambato network: an

initiative to cope with the problem of declining amphibian populations in Ecuador (Miguel A. Vazquez and David Romo); Nitates and amphibians (Tim Halliday); Froglog Shorts.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force. It is Edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA. *Froglog* can be accessed at <http://www2.open.ac.uk/biology/froglog/>

***Recovery*: March 2000, Number 15**

Issue 15 contains — North America's best kept secret: Conserving Newfoundland's rare limestone barrens flora (Luise Hermanutz); A challenge for Canadians (Elizabeth May); New findings in turtle recovery (Tom Herman); COSEWIC Update: Emergency listing of rare frog; Environment Minister unveils plan for protecting species at risk; Surveys clarify duck distribution (Tony E. Chubbs, Perry Trimper, Kathy Knox, Michel Robert, and R. Ian Goudie); CITES update: Parties to meet in Kenya (Charles Dauphiné); Canada and U.S. save shared species at risk

(Martha Balis-Larsen, Charles Dauphiné, and Susan Jewell); Recovery plan initiated for mussels (Gerry Mackie).

Recovery is a free newsletter providing information on Canadian species at risk. It is coordinated by the Canadian Wildlife Service, and edited and designed by West Hawk Associates, Inc. It is available in either english or french from Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, K1A 0H3 and is accessible at www.cws-scf.ec.gc.ca/es/recovery/archive.html

Newsletter of the Canadian Amphibian and Reptile Conservation Network 4(1)

The Winter 2000 issue contains various announcements and features the 1999 annual meeting 15-18 October, a complete listing of papers presented and an account of the field trip at the meeting. Also included are an update on Wood Turtle research by Kim Smith, articles on the herpetofauna of Pelee Island by Ben Porchuk and Robert Wilson, book review and current Canadian projects. The next annual meeting is 22-25 September 2000 at Penticton, British Columbia (for more information contact larry_halferson@pch.gc.ca or laura.friis@gems8.gov.bc.ca).

The CARCN website Part II, the reptiles is at <http://www.cciw.ca/lecowatch/dapcan>. Also given is the "AmpibiaWeb" site for the amphibian decline newsgroup posted by David B. Wake (<http://www.amphibiaweb.org>) which provides access to all aspects of amphibian biology. For membership in the Canadian Amphibian and Reptile Conservation Network contact Bruce Pauli c/o National Wildlife Research Centre, Hull, Quebec K1A 0H3.

FRANCIS R. COOK

Marine Turtle Newsletter (87)

Number 87, January 2000, 28 pages, contains: GUEST EDITORIALS: The Convention on Migratory Species and Marine Turtle Conservation; US NMFS Rejects Proposed Ban on Harvest of Sargassum Seaweed; ARTICLES: Current Status of Marine Turtles in Uruguay; Work on the Foundation for the Conservation and Recovery of Marine Life; Reproductive Span of Olive Ridley Turtles at Gahirmatha Rookery, Orissa, India; Fidelity of Male Olive Ridley Sea Turtles to a Breeding Ground; NOTES: Loggerhead Tagged in Brazil Found in Uruguay; Hawksbill turtle tagged in Brazil captured in Gabon, Africa; Exploitation of Loggerhead and Green Turtles in Egypt: Good News?; Marine Turtles Nesting in Sorong, Irian Jaya, Indonesia; LETTERS TO THE EDITORS: Which Kemp's Ridley Nest

Numbers are Correct?; MEETING REPORTS; ANNOUNCEMENTS; NEWS & LEGAL BRIEFS, RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; Fax +1 978 840 8184. MTN website is: <<http://www.seaturtle.org/mtn/>>

Book Review Editor's Report for Volume 113 (1999)

The new millennium would not be right without some disasters. No Y2K, but a virus ate my whole system in mid-December. Luckily most was backed up, but I did lose some addresses and e-mails. If anyone sent me a review by e-mail late last year and received no reply, please check.

Due to my travels for work, I am often away from mail or e-mail for a month or more. Do not panic if I do not reply for a period. I do hope that my faithful reviewers will keep in touch because there are many and I have often little time. If you see a book of interest in our New Titles, please let me know. If there is a publication that has not been listed, and should be, also let me know. I can obtain complimentary copies from publishers about 70% of the time that I request them. I always have books available for review and always welcome offers to review, whether from new or experienced reviewers.

Volume 113 was a good year for reviews. The Editor has kept me very busy by catching up to complete the volume by year end. Sixty-three reviews were published. This is average over past history, but since one issue had no reviews, it is a good number per issue. Since only 33 books were actually sent out this year for review, this represents impressive catching up. Publishers have become a little more stingy. Fifty-seven books were requested this year and only 34 received. Since many of those received were not specifically requested, this means we are not getting as good a response from the publishers as we used to. In the past I have usually received more books than I requested and usually assume about a 75% compliance when I request copies.

For those interested, my e-mail is edith@netcom.ca and address RR# 1, Moffat, Ontario L0P 1J0.

WILSON EEDY
Book-review Editor

Editor’s Report for Volume 113 (1999)

Issue mailing dates for volume 113 were: (1) 31 March 1999, (2) 7 June 1999, (3) 14 September 1999, and (4) 17 December 1999. Totals for circulation to members of the Ottawa Field-Naturalists’ Club and individual and institutional subscribers to *The Canadian Field-Naturalist* in 1999 together with those of 1998 are given in Table 1. The number of articles and notes in volume 113 is summarized in Table 2 by topic; totals for Book Reviews and New Titles are given in Table 3, and the distribution of content by page totals per issue in Table 4.

M.O.M. Printers, 300 Parkdale Avenue, Ottawa, set and printed the journal and special thanks are due Emile Holst, and to Yolande, Cecilia, Bruce and all the others of the MOM staff whose efforts make each issue possible. Wanda J. Cook proof-read the galleys for the volume. Bill Cody continued as Business Manager and handled all reprint requests and again oversaw the compilation and proof-read the Index for volume 111 which was diligently prepared by Leslie Durocher. Wilson Eedy continued as Book-Review Editor. George La Roi is summarizing the Biological Flora of Canada series. For the issue on the Canadian Wildlife Service history, I am deeply indebted to Pat Logan, editor for the CWS, for assistance by proofing galleys, page proof, and blues.

Manuscripts (excluding book reviews, notices, club or journal reports) submitted to *The Canadian Field-Naturalist* totalled 124 in 1999, an increase of 11 over 1998. Suitable manuscripts submitted to *The Canadian Field-Naturalist* have been reviewed by the following, to whom I am greatly indebted for their evaluations and constructive comments (number of manuscripts returned given in parenthesis if more than one in 1999):

Associate Editors: R. Anderson (entomology), Canadian Museum of Nature (5); Warren B. Ballard (mammalogy),

Department of Range, Wildlife and Fisheries Management, Texas Tech University, Lubbock (42); Charles D. Bird (botany), Erskine, Alberta (19); Robert R. Campbell (fish and marine mammals), Ottawa, Ontario (3); Paul M. Catling (botany), Agriculture and Agri-food Canada, Ottawa, Ontario (14); Brian W. Coad (ichthyology) Canadian Museum of Nature, Ottawa, Ontario (5); A. J. Erskine (ornithology), Canadian Wildlife Service, Sackville, New Brunswick (39); W. Earl Godfrey (ornithology), Nepean, Ontario; W. O. Pruitt, Jr. (mammalogy), Department of Zoology, University of Manitoba, Winnipeg (40).

Additional reviewers: Peter L. Achuff, Jasper National Park, Jasper, Alberta; E. M. Addison, Ecolink Science, Aurora, Ontario; Cindy Ahern, Department of Invertebrate Zoology, Smithsonian Institution, Washington, District of Columbia; Susan Aiken, Canadian Museum of Nature, Ottawa, Ontario; C. Davison Ankney, Department of Zoology, University of Western Ontario, London; Robert Bailey, Zoology Department, University of Western Ontario, London; Robin W. Baird, Pacific Whale Foundation, Kihei, Hawaii; Erin Bayne, Canadian Wildlife Service, Saskatoon, Saskatchewan; David Barton, Department of Biology, University of Waterloo, Ontario; Erin Bayne, Canadian Wildlife Service, Saskatoon, Saskatchewan; Frank S. L. Beebe, Sydney, British Columbia; Michael Berrill, Department of Biology, Trent University, Peterborough, Ontario; J. Roger Bider, Ecomuseum, Ste-Anne-de-Bellevue, Quebec (6); David Bird, Avian Science and Conservation Centre, McGill College, Macdonald Campus, Ste. Anne De Bellevue, Quebec; James P. Bogart, Department of Zoology, University of Guelph, Ontario; Gary Bortolotti, Department of Biology, University of Saskatchewan, Saskatoon; Jeff Bowman, N. B. Wildlife Research Unit, University of New Brunswick, Fredericton; Donald Bowen, Bedford Institute of Oceanography, Dartmouth, Nova Scotia; W. Sean Boyd, Pacific Research Centre, Canadian Wildlife Service, Delta, British Columbia; Ronald J. Brooks, Department of Zoology, University of Guelph, Ontario (4); Kim R. Brunt, British Columbia Ministry of Environment, Lands and Parks, Nanaimo; Evelyn L. Bull, U.S. Forest Service, Forestry and Range Sciences

TABLE 1. The 1999 circulation of *The Canadian Field-Naturalist* (1998 in parenthesis). Membership totals from Annual Report of the Ottawa Field-Naturalists’ Club, January 2000; subscription totals compiled by W. J. Cody. Forty percent of membership dues and 100% of subscriptions go to production of *The Canadian Field-Naturalist*. Members vote on Club affairs, subscribers and institutions do not.

	Canada		USA		Other		Totals	
Memberships								
Family & individual	921	(938)	30	(30)	6	(5)	957	(973)
Subscriptions								
Individuals	184	(186)	62	(61)	7	(5)	253	(252)
Institutions	181	(181)	277	(258)	39	(41)	497	(480)
Totals	365	(369)	339	(319)	46	(46)	750	(732)
TOTALS	1286	(1305)	369	(349)	52	(51)	1707	(1705)

Note: 20 countries are included under “Other” (outside Canada and United States): Institutions: Australia, Austria, Belgium, Brazil, Denmark, England (including Northern Ireland), Finland, France (St. Pierre & Miquelon Islands), Germany, Iceland, Japan, Netherlands, New Zealand, Norway, Poland, Russia, South Africa, Spain, Sweden, Switzerland.

TABLE 2. Number of articles and notes published in *The Canadian Field-Naturalist* Volume 113 (1999) by major field of study.

Subject	Articles	Notes	Total
Mammals	12.5*	11	23.5*
Birds	12.5*	10	22.5*
Amphibians + reptiles	2	3	5
Fish	3	2	5
Invertebrates	5	2	7
Plants	9	3	12
Fossils	0	1	1
Other	6**	0	6**
Totals	50**	32	82**

*One paper covered both mammal and bird data.

**A history and a compilation of selected publications for the Canadian Wildlife Service (1947-1997); and articles in News and Comment section on astronomy, COSEWIC, and two tributes.

Laboratory, La Grande, Oregon; Joanna Burger, Department of Biological Science, Rutgers/Nelson Biological Lab, Rutgers University, Piscataway, New Jersey; Robert W. Butler, Canadian Wildlife Service, Delta, British Columbia; T. L. Cade, The Peregrine Fund, Boise, Idaho; R. A. D. Cameron, Department of Extramural Studies, University of Birmingham, Birmingham, England; Lu Carbyn, Canadian Wildlife Service, Edmonton, Alberta (5); John Chardine, Canadian Wildlife Service, Sackville, New Brunswick; Philip A. Cochrane, Division of Natural Sciences, St. Norbert College, De Pere, Wisconsin; William James Cody, Agriculture and Agri-food Canada, Ottawa, Ontario (4); Joseph A. Cook, University of Alaska Museum, Fairbanks; Fred Cooke, Simon Fraser University, Burnaby, British Columbia; Laurie Consaul, Canadian Museum of Nature, Ottawa, Ontario; R. T. Coupland, University of Saskatchewan, Saskatoon; E. J. Crossman, Department of Biological Conservation, Royal Ontario Museum, Toronto, Ontario; Stan Cunningham, Arizona Game and Fish Department, Phoenix; Brenda Dale, Canadian Wildlife Service, Edmonton, Alberta; Yolande Dalpe, Agriculture Canada, Ottawa, Ontario; Stephen J. Darbyshire, Agriculture and Agri-food Canada, Ottawa, Ontario; Christian P. Dau, U.S. Fish and Wildlife Service, Anchorage, Alaska; Stephen Davis, Saskatchewan Wetland Conservation Corporation, Regina, Saskatchewan; Dirk Derksen, United States Geological Survey, Anchorage, Alaska; Ronald Dermott, Canadian Centre for Inland Waters, Department of Fisheries and Oceans, Burlington, Ontario; Andre Derochers, Centre de Recherche Biologie Foestiere et Department des Sciences du Bois et la Forêt, Université Laval, Ste-Foy, Quebec; Jack Dubois, Manitoba Museum of Man and Nature, Winnipeg, Manitoba; Graham Forbes, Wildlife Research Unit, University of New Brunswick, Fredericton; Bruce A. Ford, Botany Department, University of Manitoba, Winnipeg; B. T. Fowler (né Theresa Aniskowicz) Committee on the Status of Endangered Wildlife in Canada, Canadian Wildlife Service, Hull, Quebec (5); Bill Freedman, Department of Biology, Dalhousie University, Halifax, Nova Scotia (2); Steve H. Fritts, U.S. Fish and Wildlife Service, Denver, Colorado; Anthony J. Gaston, Canadian Wildlife Service, Ottawa (2); Amy Ganguli, Department of Range, Wildlife

and Fisheries Management Texas Tech University, Lubbock; Jim Ginns, Penticton, British Columbia; Charlotte Gjerlov, Department of Forest Sciences, University of British Columbia, Vancouver; Henri Goulet, Agriculture Canada, Ottawa, Ontario; Patrick T. Gregory, Department of Biology, University of Victoria, British Columbia; Wayne Grimm, Clayton, Ontario; Erich Haber, National Botanical Services, Ottawa, Ontario (2); Tony Hamilton, British Columbia Ministry of Environment, Victoria; Susan J. Hannon, Department of Biological Sciences, University of Alberta, Edmonton, Alberta; Fred Harrington, Psychology Department, Mount St. Vincent University, Halifax, Nova Scotia; Stephen J. Hecnar, Biology Department, Lakehead University, Thunder Bay, Ontario; J. David Henry, Klusane National Park, Haines Junction, Yukon; Alan Hildebrand, Geological Sciences Department, University of Calgary, Alberta; Karen E. Hodges, Department of Fish and Wildlife, Oregon State University, Corvallis; Erling Holm, Centre for Biodiversity and Conservation Biology, Royal Ontario Museum, Toronto (3); Stuart Houston, Saskatoon, Saskatchewan; John Huber, Department of Agriculture, Ottawa, Ontario; Ross James, Sutherland, Ontario (2); Jan Kamer, Department of Range, Wildlife and Fisheries, Texas Tech University, Lubbock; Paul Keddy, Carleton Place, Ontario; Peter Kevin, Department of Environmental Biology, University of Guelph, Ontario; Brendon Larson, Biological Sciences, University of California, Santa Barbara; Jim Leafloor, Ontario Ministry of Natural Resources, Cochrane; Robin Leech, Edmonton, Alberta; Patrick Lemons, Department of Range, Wildlife and Fisheries Management, Texas Tech University, Lubbock (3); Jon Lien, Department of Psychology and Oceans Studies Centre, Memorial University of Newfoundland, St. John's; Bradley C. Livezey, Carnegie Museum of Natural History, Pittsburgh, Pennsylvania; Nick Mandrak, Department of Biology, Trent University, Peterborough, Ontario; Mark Mallory, Canadian Wildlife Service, Iqaluit, Nunavut; Pamela Martin, Canadian Wildlife Service, Burlington, Ontario; Ross D. MacCulloch, Center for Biodiversity and Conservation Biology, Royal Ontario Museum, Toronto; Donald F. McAlpine, Natural Science Department, New Brunswick Museum, Saint John (3); G. L. Mackie, Department of Zoology, University of Guelph, Ontario (3); Bruce McLellan, British Columbia Ministry of Forests, Revelstoke; L. David Mech, Biological Resources Division, U.S. Geological Survey, St. Paul, Minnesota (5); J. Middleton, Environmental Policy Institute, MacKenzie Chown Complex, Brock University, St. Catharines, Ontario; Sterling Miller, National Wildlife Federation,

TABLE 3. Number of reviews and new titles published in Book Review section of *The Canadian Field-Naturalist* Volume 113 by topic.

	Reviews	New Titles
Zoology	25	40
Botany	9	15
Environment	15	31
Miscellaneous	5	12
Young Naturalists	—	31
Totals	54	129

TABLE 4. Number of pages per section published in *The Canadian Field-Naturalist* Volume 113 (1999) by issue.

	(1)	(2)	(3)	(4)	Total
Articles	207	63	128	104	509
Notes	0	33	22	23	78
Notices & Reports	1	7	4	7	18
Comment & Tribute	0	41	0	5	46
Annual Meeting	0	0	5	0	5
Book Reviews*	0	15	24	18	57
Index	6			31	31
Advice to Contributors	0	1	1	0	2
Totals	214	160	184	188	746

*Total pages for Book Review section include both reviews and new titles listings.

Missoula, Montana; Dave Moore, Ottawa, Ontario; John J. Moriarty, Ramsey County Parks and Recreation Department, Maplewood, Minnesota; David Mossop, Yukon College, Whitehorse; Kevin Mote, Texas Parks and Wildlife Department, Lubbock; Brian Much, The Peregrine Fund, Sheridan, Wyoming; Dennis L. Murray, Department of Fish and Wildlife Resources, University of Idaho, Moscow; David Nagorsen, Royal British Columbia Museum, Victoria (3); Joe Nelson, Department of Biological Sciences, University of Alberta, Edmonton; Robert W. Nero, Manitoba Natural Resources, Winnipeg; D. N. Nettleship, Tantallon, Nova Scotia; Mark O'Donoghue, Department of Renewable Resources, Mayo, Yukon Territory; Bart O'Gara, Lolo, Montana; Michael Oldham, Ontario Ministry of Natural Resources, Peterborough, Ontario; Jean-Pierre Ouellet, Département de Biologie et des Sciences de la Santé, Université du Québec à Rimouski, Rimouski Quebec; L. Packer, Biology Department, York University, North York, Ontario; Craig Perham, LGL Alaska Research Associates, Anchorage; Franklin Pope, Ottawa, Ontario; G. R. Robertson, Canadian Wildlife Service, Mount Pearl, Newfoundland; John S. Richardson, Department of Forest Sciences, University of

British Columbia, Vancouver (2); James A. Schaefer, Department of Biology Trent University, Peterborough, Ontario; F. W. Schueler, Oxford Station, Ontario (6); Fred Scott, Centre for Wildlife and Conservation Biology, Acadia University, Wolfville, Nova Scotia; Spencer G. Sealy, Department of Zoology, University of Manitoba, Winnipeg (2); Jim Sedinger, Institute of Arctic Biology, University of Alaska, Fairbanks; Christopher C. Shank, Natural Resources Service, Government of Alberta, Cochrane; Rick Spaulding, The Environmental Company Inc. (TEC), Santa Barbara, California; Robert Stephenson, Alaska Department of Fish and Game, Fairbanks; Kenneth W. Stewart, Department of Zoology, University of Manitoba, Winnipeg; Ian Stirling, Canadian Wildlife Service, Edmonton, Alberta (2); W. Daniel Svedarsky, Northwest Experimental Station, University of Minnesota, Crookston; John Therberge, Faculty of Environmental Studies, University of Waterloo, Ontario; Ian D. Thompson, Canadian Forest Service, Sault Ste. Marie, Ontario; Lance Verkmeire, Department of Range, Wildlife and Fisheries Management, Texas Tech University, Lubbock; Mark Wallace, Department of Range, Wildlife and Fisheries Management, Texas Tech University, Lubbock; Heather A. Whitlaw, Lubbock, Texas (2); Oystein Wiig, Zoological Museum, University of Oslo, Norway; Kathleen Wilkinson, Calgary, Alberta; Mike Zicus, Minnesota Department of Natural Resources, Bemidji; Aaron Zuccolin, Coquitlam, British Columbia.

I am also indebted to David Moore, President of the Ottawa Field-Naturalists' Club, the Club Council, Chairman Ron Bedford and the Publications Committee of the OFNC for continuing their support, to Stephen Bridgett of the OFNC Computer Committee; to the Canadian Museum of Nature for access to its library and the facilities at the Natural Heritage Building, 1740 Pink Road, Aylmer, Quebec, and to Joyce for continuing encouragement at home.

FRANCIS R. COOK
Editor

Erratum: *The Canadian Field-Naturalist* 114(1): Kurczewski Figure 13, page 14

Kurczewski, Frank E. 2000. History of White Pine (*Pinus strobus*)/oak (*Quercus* spp.) savanna in southern Ontario, with particular reference to the biogeography and status of the Antenna-waving Wasp, *Tachysphex pechumani* (Hymenoptera: Sphecidae). *Canadian Field-Naturalist* 114(1): 1–20.

On page 14, Figure 13 was incompletely repro-

duced. Missing were localities 1 through 12, open square symbols, depicting locations of nesting aggregations. The correct figure with all localities (including the open circles where the species was not found in apparently suitable habitat) is reproduced below. For listing of all localities see 114(1) caption page 15.



Book Reviews

ZOOLOGY

The Birder's Bug Book

By Gilbert Waldbauer. 1998. Harvard University Press, Cambridge Massachusetts and London, England, 290 pp., illus. U.S. \$27.95

The chapter titles grabbed my attention: *Bugs That Birds Eat, The Bugs Fight Back, Bugs that Eat Birds, The Birds Fight Back, Bugs That Eat People, People Fight Back*. Delving into the the book, I soon found the contents to be as interesting as the chapter titles. The writing is clear, enlivened with personal anecdotes and sprinkled with vivid description. The larva of a moth or butterfly "is essentially a digestive system on a caterpillar tread." Nightjars "are the night shift of the insect-eating aerialists." There is even a poem by Robert Frost. The numerous drawings are effective in illustrating points made in the text, as is the portfolio of coloured photographs in the centre of the volume. On the lower right-hand corner of every odd-numbered page is a sketch of a pileated woodpecker. The position of the woodpecker is varied so that, when the pages are flipped, you see an animation of the bird chiselling a hole in a tree. Canadian readers will appreciate the fact that the author shows some awareness that life exists north of the 49th parallel. There are repeated references to birds and insects in the various regions of our country.

As well as a being a good read, the book has value as a reference volume. There are bibliographies for each chapter; a comprehensive index; and a helpfully illustrated section on the taxonomy of insects with a summary of the principal features of the major orders — enough information "so that you can recognize at least some of the members and so that you know at least a bit about how some of them live."

The humorous, eye-catching dust cover photo of a satisfied fledgling screech owl beginning to munch a

colourful cecropia moth is, itself, almost worth the price of the book.

In the experience of the author, "almost all birders . . . view a bird as more than a checkmark on a list. They are curious about its life history and behaviour." This has certainly been true for me, a birder for some 30-years standing. *The Birder's Bug Book*, however, launched me into a crucial area of the natural history of birds to which I have given scant attention and which greatly enhanced my understanding of bird life. I got an entertaining education in bugs which has left me with a new appreciation of their ecological significance.

The book is not just concerned with birds and insects; birders get coverage as well. There is information about bugs that sting, bite, harass and live on people and about both the helpful and destructive ways that humans have responded.

The final chapter, *Disappearing diversity*, is a plea for greater efforts to reverse the alarming pace of extinctions. "We have the capacity to destroy or to preserve. So far, from an ecological perspective, we have been mainly destroyers . . . we unthinkingly wipe out whole habitats and exterminate species by the thousands. In so doing we both threaten our ultimate well-being and diminish our spirit."

Perhaps the most significant contribution of *The Birder's Bug Book* is to remind us that "we are but one aspect of the planetary web of life" and "can understand ourselves only in the context of all life."

Treat yourself to this engaging book. Share it with others. It's a treasure.

GARTH C. NELSON

529 Dalhousie Crescent, Saskatoon, Saskatchewan
S7H 3S5, Canada

Cowbirds and Other Brood Parasites

By Catherine Ortega. 1998. The University of Arizona Press, Tucson, Arizona, 85721. 371 pp., Illus. U.S. \$65.00.

The central focus of this comprehensive work on brood parasites is the Cowbird, which is often blamed

for the decline in the number of songbirds. However mankind is equally to blame for altering the landscape and creating better conditions for the Cowbird to flourish by increasing forest fragmentation and therefore "edge" habitat. This absorbing work is intended primarily for graduate students, those in managerial

positions in various agencies and nature preserves, and ecological consultants. It will also interest birdwatchers who would like to gain a more thorough understanding and appreciation of cowbirds and other brood parasites such as ducks and cuckoos. There is a summary of the areas where much is not known and recommendations for further research. Nearly 40 pages of literature are cited, some of the papers dating to the early 19th century, but the accumulated wisdom has not resulted in effective controls on Cowbird parasitism.

The Brown-headed and Shiny Cowbirds (with the Shiny Cowbird expanding northwards to eastern Canada) have evolved cunning adaptation strategies for their survival. Their eggshells are thicker (which makes it more difficult for the host to pierce), incubation time is usually shorter than the host eggs, the nestling gape is larger (therefore it is fed first), and in many cases the egg size and colour are almost identical to the host. Since Cowbirds are known to parasitize over 200 species this means that a wide variety of egg colour and markings are possible — but of course an individual Cowbird can only lay one particular colour. Speed is essential to successful undetected laying, and it takes only 40 seconds to fly in, lay, and depart. Host species take up to 2 minutes to lay an egg. The hosts are not always duped, and 30 songbird species will cover a first clutch containing a Cowbird

egg with a new floor and then lay another clutch; some hosts will pierce the intruder egg with their beak and remove it; some abandon the nest and rebuild. Many of the alien nestlings fledge, though, often at the cost of the life of the rightful occupants. Birds usually imprint on the species of the parent which feeds it, humans included, but Brown-headed Cowbirds join their own species as adults and are not imprinted on their foster parents.

The author discusses management control measures which, by and large, have not been successful. The exception is the effort to reduce brood parasitism on the Kirtland's Warbler. Trapping, shooting, and egg removal have made little difference to Cowbird populations elsewhere since to reduce them would require making fundamental changes to habitat. If Cowbirds were unable to parasitize perhaps they might learn to make nests and develop brood patches!

This is a well-written fascinating book, scientific but not impenetrable, and valuable to all the groups mentioned above. Line drawings of the parasitic species would have been an improvement over the poor photographs, but the Tables and Appendices are crystal clear and evidence of prodigious research

JANE ATKINSON

255 Malcolm Circle, Dorval, Quebec H9S 1T6, Canada

Cognitive Ecology

Edited by Reuven Dukas. 1998. University of Chicago Press, Chicago. ix+420 pp. Cloth U.S.\$95, paper U.S.\$43.50.

For at least two decades researchers into the how and why of animal behaviour, i.e. its psychology and ecology, have realized that these two domains need to be considered within the same framework. The present volume, subtitled "the evolutionary ecology of information processing and decision making", is aimed toward this end. The contributing authors are well-known behavioural ecologists, primarily from North America. The successive chapters deal with all major aspects of animal behaviour. Communication is excellently treated in two chapters. The evolution and neural representation of signals are examined by Magnus Enquist and Anthony Arak, particularly for peak shifts, strategic models, evolutionary aesthetics, and the strengths and weaknesses of connectionist networks. The case study of song sparrows by Michael Beecher and co-workers well emphasizes the need for field work using more than playback techniques, and highlights rules of learning and detailed analysis

(although the foundational problem of similarity of songs is not addressed). David Sherry provides a well-organized review of spatial memory, especially the role of the hippocampus. Aspects of risk-sensitive foraging are carefully dissected by Melissa Bateson and Alex Kacelnik, and insightfully linked to areas such as Pavlovian conditioning and networks. Other chapters thoroughly review learning, navigation, constraints on information processing, foraging while avoiding predators, and choice of partners socially and sexually. The comprehensibility of the illustrated data, generally drawn from previous publications, varies considerably. Dukas provides helpful, if somewhat choppy, opening and closing overviews.

As intended, the theme of an evolutionary approach to animal cognition and information processing runs as a Leitmotif throughout the material. Beyond the specifics of each topic examined, there are important recurring issues including appropriate experimental methodology, critical interpretation, and the use of appropriate quantitative models, especially neural networks and dynamic approaches. The inevitable redundancy of multi-authored

works is par for the course. Dukas and several authors well indicate directions for further research. (And Western naturalists will be glad to read the acknowledgement to “the spiritual hospitality of British Columbia’s wilderness” (page 165).) It is too much to say that cognitive ecology is a “new discipline” (page 396) but the growth of interest in

this area, including the appearance of this book, are welcome developments.

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BOTANY

A Guide to the Ferns of Grey and Bruce Counties, Ontario

By The Bruce-Grey Plant Committee (Owen Sound Field-Naturalists). 1999. Stan Brown Printers Limited, Owen Sound, Ontario. 119 pp. Paper \$15.00. Available from: The Bruce-Grey Plant Committee, c/o The Owen Sound Field-Naturalists, Box 401, Owen Sound, Ontario N4K 5P7 and The Toronto Field-Naturalists, 2 Carlton Street, No. 1519, Toronto, Ontario M5B 1J3

This is not just a little book about the ferns found in a small area but a wonderful treatment of 50 species which represent 3 1/2% of the total number of species comprising the flora of Grey and Bruce Counties. The authors don’t just talk about the ferns however. In the introduction they describe the Location and Area which lies in the northwestern part of southern Ontario including part of the Niagara Escarpment, the Bruce Trail and Sauble Beach, an area which “is known for its natural beauty and clean environment”. Also in the introduction are descriptions of the Geology, Physiology, Climate, Human History, Vegetation, and interesting comments on a question “Why are there so many species of ferns in Grey and Bruce Counties?”

This is followed by a section entitled “Introducing Ferns”. Here they remind the readers of the ancient history of ferns from 430 to 400 million years ago, the life cycle of ferns, fern parts, and how to identify ferns which is followed by two pages of excellent line drawings depicting the various terminologies used in fern descriptions.

Then comes “Ferns Grouped for Identification Purposes”.

A. Where to Look for Ferns

- 1.(a) Mature Shady Woodland (repastured for at least 50 years)
- 1.(b) Mature Shady Woodland with Large Dolostone Boulders
- 2. Damp Rich Soil with open Shade
- 3. Dolostone Crevices, Rockface Dolostone, Alvars, or Talus Rubble
- 4. Dry Abandoned Pastures, Old Sand Dunes, Reforestation Areas

- 5. Thin or Open Shade with Acidic Soil
- 6. Wet Swampy Areas or with *Sphagnum*

Following each of the above habitats are the common names of ferns found in them.

B. Evergreen Ferns

C. Frond Divisions

An easy key to groups of species together with common and scientific names.

D. Situation of Sporangia

Another easy key to groups of genera or species together with common and scientific names.

Then there are 77 pages of most fascinating information on the families, genera, and species, a description, a line drawing, and a distribution map depicting the townships in which each fern has been found and nine pages of colour photographs.

Two tables are also useful:

- 1. The Rare Ferns of Grey and Bruce Counties
- 2. The Distribution of Fern Species in Grey and Bruce Counties (included is a map depicting the Townships).

Of special interest are three historical records “fern mysteries” of Water Clover (*Marsilea quadrifolia*), Indian’s Dream (*Aspidotis densa*), and Curly Grass (*Schizaea pusilla*), together with a more recent report of Broad Beech Fern (*Thelypteris hexagonoptera*) which was noted from the Lion’s Head area in 1993 but could not be found in 1998.

The work is completed by information on “Grown Ferns from Spores”, a Glossary, References, and Bibliography, an Index to Fern Names, and a request for a report of new or rare species in Grey and Bruce Counties.

The authors are to be congratulated for this most useful and welcome publication.

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ENVIRONMENT

Ecosystem Management for Sustainability: Principles and Practices Illustrated by a Regional Biosphere Reserve Cooperative

Edited by John D. Peine. 1999. Lewis Publishers, Baton Rouge. 500 pp.

Sustainability has become one of the environmental buzzwords and issues of the 90s. There has been, and continues to be a great deal of discussion as to what this term means and how is it to be achieved. The discussion has occurred more in terms of theory and not necessarily on how to practice sustainability on an ecosystem wide basis. Dr. Peine has attempted to provide a book which provides the practical side of the debate. The book is meant to connect theory with the experiences of practicing managers.

The fifty-one contributors provide us with 23 chapters covering concepts, case studies, components of ecosystem management, and the future. The book outlines the benefits of the cooperative approach and benefits which have resulted. This is not to indicate the process has been completed but it is an evolving process. The major portion of the work discussed originates from the Southern Appalachian Man and the Biosphere (SAMAB) program which could be viewed as a US national model in ecosystem management. (Chapter 6 does attempt to provide a more global perspective with a comparison with the Prioksko-Terrasny Reserve in Russia).

The components of ecosystem management section of the book will most likely prove to be the more referenced section for on the ground managers. This section provides assessments of issues such as bioinvasion, re-introduction ecosystem processes, management of rare species, and management of species with large territorial requirements to name a few. The reader is provided historical perspectives, solutions tried, and results from SAMAB to compare with when possibly attempting to deal with similar situations.

"Ecosystem Management for Sustainability" provides the reader with a working example of an ongoing process from which to learn. The readership to gain most from Dr. Peine's efforts will be those already involved in research and management of bio-reserves. There also exists the potential for the student of natural resources management to gain an understanding of theory from the practical examples.

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MISCELLANEOUS

The Book of Nature, Natural History in the United States 1825-1875

By Margaret Welch. 1998. Northeastern University Press, Boston. 289 pp., illus. U.S. \$50.00.

The 19th century was a time of many discoveries and ideas. The exploration and exploitation of the American and Canadian west were reaching their zenith, and the natural world around these explorations and even on the eastern home front were beginning to be formulated. As natural treasures were brought home and described, an audience developed that not only recognized the beauty of Nature, but also the beauty of art in a Nature theme. Margaret Welch examines such a period in *The Book of Nature, Natural History in the United States 1825-1875*.

With the growing prestige and importance of the natural surroundings that foreign countries placed on interpreting nature through word and art, the Americans felt second class. There was a nationalist need for correcting the inaccuracies in the primarily English scientist, who were only able to view works

of American Nature in their dead form or by idle anecdotes provided by correspondence. The Americans wanted to illustrate the unique grandeur of their own back yard. This, by no accident, coincided with the rise of the quality of printers and their materials, scientists, and artists, all of whom were beginning demonstrate their own high quality.

The resulting, often massive, productions catered to the eastern, affluent clientele, and were costly and time consuming to produce. Alexander Wilson's *American Ornithology* would fetch a handsome price of \$120 in the early 19th century and this was produced only when sufficient subscribers were enlisted. The time and money involved in making the illustrations were more often a love of the work rather than a love of profit. But with the establishment of faster transportation, the development of new printing technology, and national disorientation after the civil war, together "marked the end of American natural history illustration on the grand

scale.” The residue of interest saw “the rare union of art, nature, and science . . . fragmenting.” The advent of Darwin’s grand synthesis in 1859 also played a part, bringing the stamp collecting of nature into a more serious, and often dry, literary state.

An often overlooked facet of all this 19th century naturalizing is that even then the witnesses of nature were observing the slow decimation of species. “The territorial expansion” Welch notes “provoked steady commentary over the disappearance of wildlife and the transformation of the wilderness.” Though these warning shots were fired, mostly by the volunteer local collectors like Smithsonian’s Spencer Fullerton Baird, very few took notice. Bedazzled by the variety of the works of Nature at the same as paying more attention to the demands of the day, a national environmental consciousness would be a long time in coming.

The recurring theme of Welch’s study, however, is the book itself; the technique of producing the large folios of the like of the famed Audubon, the book as a resource (which we today take for granted with our libraries and cyberspace), and its rarity for

those in the non-eastern centers who were of curious mind but lacking in depth of pocket. “The scarcity” of the book, remarks Welch, “led to an intensity of the reading experience.” It was glorious, almost sacred event to sit down and thumb through Audubon’s *Quadrupeds of North America*, or Thomas Nuttall’s *Manual of Ornithology*. The “books were the conduit to their favorite subject and activity.”

The Book of Nature is a strong summation of an era of American nationalism, the spiritualness of Nature, the rise of “professional” science and the expansion of a mode of communication. The work would have been stronger if more detail were provided on early-mid 19th century printing techniques; nevertheless, Welch’s history lesson is a worthwhile perspective, especially as we saunter down a new path, less populated by nature, holding our keyboard in one hand and a mouse in another.

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YOUNG NATURALISTS

Hungry Hollow: The story of a natural place

By A. K. Dwedney. 1998. Published by Copernicus, Springer-Verlag New York Inc., New York. 233 pp., Illus. U.S.\$26.00.

Hungry Hollow is a fictional composite area of the eastern deciduous forest region of North America, and contains a river-valley, an upland forest, and a floodplain meadow. The natural history of the hollow is described with most of its inhabitants, ranging from micro-organisms to trees, the geology, the birds, reptiles, and plants. It is written in a narrative style, allocating human christian names to some of the animals and describing events in their lives, complete with conversations between species. Unusually in a book of this kind, correct terminology is used, but a scientific description of how spores reproduce is followed by a fanciful description of the reaction of a raccoon to eating a poisonous mushroom. Descriptions of how plants grow, how soils are formed, and of the Order of the plant and animal

Kingdoms are clearly written. There is an emphasis on the inter-connectedness of all living things throughout the book and how nature constantly recycles living matter. This would be a book to recommend to someone who has shown an interest in natural history but has no experience or background, or to a young person taking a natural resources or wildlife course for the first time. It is easier to read than a textbook on those subjects, but the conversations and supposed thought processes of the animal characters detract from the solid information the book contains. The author writes for Scientific American and is working with watershed authorities on the restoration of a forest/wetland site in southern Ontario.

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NEW TITLES

Zoology

- ***The amphibians of the former Soviet Union.** 1999. By S. Kuzmin. Pensoft, Sofia, Bulgaria. vi + 538 pp., illus. U.S. \$98 + U.S. \$12 Shipping.
- ***Animals of the world.** 1999. By Firefly Books, Willowdale, Ontario. 512 pp., illus. \$19.95.
- †**Birder's Mexico.** 1999. By R. H. Wauer. Texas A & M University Press. College Station. xxvii + 304 pp., illus. U.S. \$18.95.
- ***Birds of Kenya and northern Tanzania: field guide edition.** 1999. By D. A. Zimmerman, D. A. Turner, and D. J. Pearson. Princeton University Press, Princeton. 576 pp., illus. Cloth U.S. \$39.50; paper U.S. \$29.95.
- ***The Condor's shadow: the loss and recovery of wildlife in America.** 1999. By D.S. Wilcover. Freeman, New York. xix + 339 pp., illus. U.S. \$24.95.
- ***Fishes of Nova Scotia: species recorded in the accession books of Harry Piers from 1899 to 1939.** 1999. By J. Gilhen. Nova Scotia Museum, Halifax. 154 pp., illus. \$20.
- ***Handbook of the birds of the world volume 5: barn-owls to humming birds.** 1999. Edited by J. del Hoyo, A. Elliott, and J. Sargatal. Lynx Edicions, Barcelona. 759 pp., illus. U.S. \$185.
- †**Mammals of North America: temperate and arctic regions.** 1999. By A. Forsyth. Firefly Books, Willowdale, Ontario. 350 pp., illus. \$40.
- †**The miracle of flight.** 1999. By S. Dalton. Firefly Books, Willowdale, Ontario. 184 pp., illus. \$40.
- †**Models of adaptive behavior: an approach based on state.** 1999. By A. I. Houston and J. M. McNamara. Cambridge University Press, New York. ix + 378 pp., illus. Cloth U.S. \$80; paper U.S. \$34.95.
- †**Mammals of North America: temperate and arctic regions.** 1999. By A. Forsyth. Firefly Books, Willowdale, Ontario. 350 pp., illus. \$40.
- †**The nature of hummingbirds: rainbows on wings.** 1999. By H. Thurston. Greystone Books, Douglas and McIntyre, Vancouver. 128 pp., illus. \$34.95.
- †**The nature of spiders: consummate killers.** 1999. By A. Mason. Greystone Books, Douglas and McIntyre, Vancouver. 128 pp., illus. \$34.95.
- ***Patterns of distribution of amphibians: a global perspective.** 1999. Edited by W. E. Duellman. Johns Hopkins University Press, Baltimore. viii + 633 pp., illus. U.S. \$69.95.
- †**The pheasants of the world: biology and natural history.** 1999. By P.A. Johnsgard. 2nd edition. Smithsonian Institution Press, Washington. xviii + 398 pp., illus. U.S. \$50.
- †**Rare birds of British Columbia.** 1999. By D. F. Fraser, W. L. Harper, S. G. Cannings, and J. M. Cooper. Ministry of Environment, Lands, and Parks, Victoria. 233 pp., illus.
- †**Rare freshwater fish of British Columbia.** 1997. By S. G. Cannings and J. Ptolemy. B. C. Ministry of

Environment, Lands, and Parks, Victoria. xiv + 214 pp., illus.

- ***Salamanders of the United States and Canada.** 1998. By J. Petranks. Smithsonian Institution Press, Washington. xvi + 587 pp., illus. + plates. U.S. \$60.

- †**The Smithsonian book of North American mammals.** 1999. Edited by D.E. Wilson and S. Ruff. Smithsonian Institution Press. Canadian distributor University of British Columbia Press, Vancouver. xxv + 750 pp., illus. \$95.

Botany

- Northeastern fern identifier.** 1999. By R. S. Mitchell, L. Danaher, and G. Steeves. New York State Museum, Albany. U.S. \$19.95 + U.S. \$4 shipping.

- †**Phycology.** 1999. By R.E. Lee. 3rd edition. Cambridge University Press, New York. x + 614 pp., illus. Cloth U.S. \$100; paper U.S. \$44.95.

- ***Vanishing halo: saving the boreal forest.** 1999. By D. Gawthrop. Greystone Books, Douglas and McIntyre, Vancouver. xii + 225 pp. \$19.95.

Environment

- ***Ecological assembly rules: perspectives, advances, retreats.** 1999. Edited by E. Weiher, and P. Keddy. Cambridge University Press. New York. xii + 418 pp., illus. U.S. \$90.

- †**Encounters with nature: essays by Paul Shepard.** 1999. Edited by E. R. Shepard. Island Press, Washington. xxix + 223 pp. U.S. \$24.95.

- ***A guide to field guides.** 1999. By D. Schmidt. Libraries Unlimited, Englewood, Colorado. xxvi + 304 pp., U.S. \$65 in North America; U.S. \$78 elsewhere.

- ***The living planet: biodiversity, science, and policy in crisis.** 1999. Edited by J. Cracraft and F. T. Grifo. Columbia University Press, New York. xi + 311 pp., illus. Cloth U.S. \$60; paper U.S. \$28.50.

- †**Secret worlds.** 1999. By S. Dalton. Firefly Books, Willowdale, Ontario. 159 pp., illus. \$35.

- †**Status and trends of the nation's biological resources.** 1998. Edited by M. J. Mac, P. A. Opler, C. E. P. Haecker, and F. D. Doran. U.S. Geological Survey (Available from Government Printing Office, Washington) 2 volumes, xi + 964 pp., illus. U.S. \$98.

Miscellaneous

- Beyond Malthus: nineteen dimensions of the population challenge.** 1999. By L. R. Brown, G. Gardner, and B. Halweil. Norton, New York. 167 pp., U.S. \$13.

- A sense of place: teaching children about the environment with picture books.** 1999. By D. A. Kriesberg. Teacher Ideas Press, Englewood Colorado. xxvi + 145 pp., U.S. \$23.50.

- ***Servants of nature: a history of scientific institutions, enterprises, and sensibilities.** 1999. By L. Pyenson and S. Sheets-Pyenson. Norton (Canadian distributor Penguin Books, Markham) xi + 496 pp. + plates.

†**Shield country: the life and times of the oldest piece of the planet.** 1999. By J. Bastedo. Red Deer Press, Red Deer, Alberta. x + 271 pp., illus. \$22.95.

Books for Young Naturalists

Look who lives in the rain forest. 1999. By A. Baker. Peter Bedrich Books, New York. 32 pp., illus. U.S. \$14.95.

A new duck: my first look at the life cycle of a bird. 1999. By P. Hickman. Kids Can Press, Buffalo. 16 pp., illus. U.S. \$6.95.

A new frog: my first look at the life cycle of an amphibian. 1999. By P. Hickman. Kids Can Press, Buffalo. 16 pp., illus. U.S. \$6.95.

†**Noses that plow and poke.** 1999. By D. Swanson.

Greystone Books, Douglas and MacIntyre, Vancouver. 30 pp., illus. Cloth \$14.95; paper \$6.95.

Science fair success, revised and expanded. 1999. By R. Bombaugh. Enslow, Springfield, New Jersey. 128 pp., illus. U.S. \$19.95.

Snakes. 1999. By C. Robinson. Heineman Library, Des Plaines, Illinois. 24 pp., illus. U.S. \$13.95.

†**Tails that talk and fly.** 1999. By D. Swanson. Greystone Books, Douglas and McIntyre, Vancouver, 30 pp., illus. \$6.95.

†**Your are the earth: from dinosaur breath to pizza from dirt.** 1999. By D. Suzuki and K. Vanderlinden. Greystone Books, Douglas and McIntyre, Vancouver. 128 pp., illus. \$24.95

*Assigned for review

†Available for review

Advice for Contributors to *The Canadian Field-Naturalist*

Content

The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

Manuscripts

Please submit, **to the Editor**, in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. All authors should have read and approved it. Institutional or contract approval for the publication of the data must have been obtained by the authors. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

Print the manuscript on standard-size paper, **double-space throughout**, leave generous margins to allow for copy marking, and **number each page**. For Articles and Notes provide a bibliographic strip, an abstract and a list of key words. Generally, words should not be abbreviated but use SI symbols for units of measure. The names of authors of scientific names should be omitted except in taxonomic manuscripts or other papers involving nomenclatural problems. "Standard" common names (with initial letters capitalized) should be used at least once for all species of higher animals and plants; all should also be identified by scientific name.

The names of journals in the Literature Cited should be written out in full. Unpublished reports should not be cited here but placed in the text or in a separate Documents Cited section. List the captions for figures numbered in arabic numerals and typed together on a separate page. Present the tables each titled, numbered consecutively in arabic numerals, and placed on a separate page. Mark in the margin of the text the places for the figures and tables.

Check recent issues (particularly in literature cited) for journal format. Either "British" or "American" spellings are

acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary and le Grand Larousse Encyclopédique** are the authorities for spelling.

Illustrations

Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

Reviewing Policy

Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

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Limited journal funds are available to help offset publication charges to authors with minimal financial resources. Requests for financial assistance should be made to the Business Manager when the manuscript is accepted.

Reprints

An order form for the purchase of reprints will accompany the galley proofs sent to the authors.

FRANCIS R. COOK, Editor
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Cover: Mountain Beaver (*Aplodontia rufa*) haypiles and burrow entrance in an Engelmann Spruce (*Picea engelmannii*) and Amabilis Fir (*Abies amabilis*) forest in the upper Copper Creek drainage, British Columbia. Plants in the haypiles include Indian Hellebore (*Veratrum viride*), Arctic Lupine (*Lupinus arcticus*) and Sitka Valerian (*Valeriana sitchensis*). See article pages 476–490. Photo courtesy of Les W. Gyug.

Range, Habitat, and Population Size of the Eastern Mole, *Scalopus aquaticus*, in Canada

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The Eastern Mole, *Scalopus aquaticus*, although widespread in North America, is confined in Canada to a small area of 350 km² (35 000 ha) in southern Essex County and adjacent Kent County (now Municipality of Chatham-Kent) in southwestern Ontario. With the exception of Point Pelee National Park, most of the habitat available to Eastern Moles within the Canadian range has been converted to agriculture or urban uses incompatible with mole habitation. Approximately 4.2% of the land area remains as natural habitat suitable for moles. We calculate the total area of natural habitat available to the species in Canada at 1060 ha of which 810 ha are contained within Point Pelee National Park. This area could support 2120–12720 moles at a density of 2–12 moles per hectare. During the last century, the range of the species appears to have expanded slightly to the east and west, but continued expansion will be constrained by soil types unsuitable for mole habitation that occur just beyond the present range.

Key Words: Eastern Mole, *Scalopus aquaticus*, range, habitat, population size, Ontario.

The Eastern Mole is the only species in the genus *Scalopus*. According to some authorities, there are 16 subspecies (Yates and Schmidly 1978); Eastern Moles in Canada belong to the largest of these subspecies, *S. aquaticus machrinus*, sometimes called the Prairie Mole. In its Canadian range, the Eastern Mole is not sympatric with the two other mole species found in eastern Canada, Brewer's Mole, *Parascalops breweri*, and Star-nosed Mole, *Condylura cristata*.

The "global rank" assigned to the species is G5 (very common). It is listed as Vulnerable by the Ontario Ministry of Natural Resources based on the COSEWIC Vulnerable designation of 1980. The Natural Heritage Information Centre for Ontario has assigned the species a S₁ S₂ rank (extremely rare to very rare) and is "tracking" information on occurrences of the species. None of these designations confer legal protection to the species. In 1980, the status of Vulnerable was assigned to the Eastern Mole in Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This status was reassigned in 1998. Probably the largest population of Eastern Moles in Canada is found in Point Pelee National Park where the species is legally protected. Smaller populations are found in Conservation Areas

owned by Conservation Authorities where they are also legally protected.

The species is almost entirely fossorial (Harvey 1976; Peterson 1966), but it does occasionally come to the surface as evidenced by roadkills at Point Pelee National Park and kills by owls and domestic cats (Baker 1983). Eastern Moles build two types of tunnels — near-surface tunnels of 3.2–3.8 cm diameter in which the earth loosened by the forefeet is pressed to the upper side of the tunnel causing a raised ridge to form on the soil surface, and deep, permanent galleries with diameters of 5.5 cm (Baker 1983) at depths of 10 to 60 cm in which the soil is actually excavated and then pushed into other tunnels or onto the surface to form a molehill (also known as a "pushup") (Banfield 1974). Figure 3 shows a molehill found in Kent County, Ontario.

Harvey (1976) found that moles were active throughout the year. Surface tunnels were used when air temperatures were as low as -12°C. He found moles were active at any time of the day but especially from 8:00 a.m. to 2:00 p.m. and 11:00 p.m. to 4:00 a.m. Eastern Moles use their tunnels to forage for invertebrates. The diet includes earthworms, beetle adults and larvae, ants and vegetable matter. According to Jackson (1961), at least 80% of the mole diet consists of earthworms and adult and lar-

val ground-living insects. A study by Whitaker and Schmeltz (1974) in Indiana (as reported in Mumford and Whitaker 1982) found that the most important food items were earthworms at 26.8% of the total volume and insect larvae at 23.3%. Seeds constituted 7.3%. They also found that moles eat ants, especially in the pupal stage. Eastern Moles in Canada seem attracted to ant hills — an ant hill within a mole's home range will exhibit foraging tunnels around it. In *The Mammals of Canada*, Banfield (1974), citing other sources, described the diet as 31% earthworms, 29% insect larvae, 23% adult insects and 13% vegetable matter. The area now occupied by moles in Canada did not support a worm fauna until European settlement circa 1800 A. D. (Reynolds 1977). The large percentage of earthworms in the diet raises the question of mole diet prior to the introduction of earthworms to Ontario. No dietary data could be found for the Ontario population.

That the species plays an important role in the ecology of the woodlands it inhabits is obvious to even the casual observer. The amount of soil being lifted, shifted and mixed from depths of up to 60 cm is impressive and compounded by centuries of occupation could be at least as significant as that attributed to earthworms. Darwin (1881) calculated that the average British earthworm population of 53 767 per acre was shifting ten tons of earth per year. Patches of mineral soil are created by mole activity and these are likely important for the establishment of some plant species and for the life histories of other organisms.

Range

The Eastern Mole has the widest range of any North American mole species. From the northern portion of the Mexican State of Tamaulipas, it extends north into the United States of America to southeastern South Dakota, east to Massachusetts and south to the southernmost tip of Florida (Yates and Pedersen 1982). This encompasses most of the central and eastern United States (Figure 1). In Canada, collections and recent sightings have been restricted to four southern and eastern townships of Essex County, Ontario (Table 1; Figure 2). Canadian specimens at the Royal Ontario Museum, Toronto, and the Canadian Museum of Nature, Ottawa, and records from the Atlas of the Mammals of Ontario (Dobbyn 1994) are all from these four townships (Colchester South, Gosfield South, Gosfield North and Mersea).

In 1911, Saunders (1932) examined a mole specimen reputed to have been collected at the Town of Strathroy, in Middlesex County, a distance of 120 km east of the presently known range and in the same publication reported another observation from



FIGURE 1. Range of the Eastern Mole in North America (after Jones and Birney 1988).

near the Town of Rodney, in Elgin County, a distance of 84 km from the present range. Macauley (1980*) was unable to locate the Strathroy specimen for verification and all Canadian specimens of *Scalopus aquaticus* in the Canadian Museum of Nature in Ottawa, examined by G. Waldron, were collected at Point Pelee National Park. Therefore, the Strathroy station mapped as a "National Museum record" by Macauley (1980*) is presumably based on Saunders' (1932) report in *Notes on the Mammals of Ontario* which reads as follows:

"Common locally in Essex county near Leamington only. Point Pelee is doubtless the area of greatest abundance, but I saw some workings near Harrow, some twenty miles west of the point in June, 1909; and in November, 1910, a newspaperman from Rodney described one that was taken nearby that autumn. In 1911, I saw one in the possession of Mr. Lamotte at Strathroy, which had been taken near that town some years previously. All other reports I have received are more likely to be of the Brewer mole..."

During the 1997 fieldwork for this study, 360 hours of trapping effort (5 Nash Choker Loop Traps, each set for 72 hrs) at a site in Strathroy yielded a single specimen of Brewer's Mole [Hairy-tailed Mole]. Mole works at Rodney, Elgin County, also appeared to be of the latter species. Peterson (1966), Banfield (1974) and van Zyll de Jong (1983) do not accept Saunders' records for Rodney and Strathroy as Eastern Moles.

There are seventeen Canadian specimens of Eastern Mole in the collections of the Royal Ontario Museum. Eleven of these were collected at Point Pelee, three at Leamington and three at Kingsville. The fieldwork associated with this study has confirmed that these locations support moles and has

*See Documents Cited section.

TABLE 1. Sites where Eastern Mole works were observed in 1997 (outside Point Pelee National Park)

Name of Site	Location	UTM Coordinate
Kent County (Chatham-Kent)		Projection Square 40
1. Two Creeks Conservation Area	Wheatley	793 635
2. Bank of West Branch of Two Creeks	Wheatley	790 601
Essex County		
3. Fairview Cemetery	Wheatley	789 601
4. Kopegaron Conservation Area	Mersea Twp.	765 591
5. Evergreen Memorial Cemetery	Leamington	650 560
6. Seacliff Park	Leamington	671 543
7. Harrow Park	Harrow	414 546
8. Cedar Creek Conservation Area	Colchester South Twp.	487 543
9. New Settlement Woods	Colchester South Twp.	414 522
Environmentally Significant Area (E.S.A.)		
10. Arner Point Conservation Area	Gosfield South Twp.	497 542
11. Harrowood Retirement Community	Harrow	409 548
12. Holy Family Retreat House	Oxley	434 501
13. Klie's Sugar Bush	Gosfield South Twp.	462 535
14. G. Moulard farm	Mersea Twp.	740 586
15. Mill Creek ravine	Kingsville	554 548
16. 1060 Point Pelee Drive (Essex Rd. 33)	Mersea Twp.	713 497
17. White Oak Woods E.S.A.	Mersea Twp.	734 603
18. Bennie Woods	Leamington	698 538
19. Cinnamon Fern E.S.A.	Mersea Twp.	727 565
20. Sweetfern Woods E.S.A.	Mersea Twp.	726 627
21. Greenbrier Woods E.S.A.	Gosfield North Twp.	641 640
22. Oxley Poison Sumac Swamp E.S.A.	Colchester South Twp.	452 526
23. Kingsville Golf & Curling Club	Gosfield South Twp.	535 555
24. Union Ravine	Gosfield South Twp.	612 553
25. Wilson's Rainbow Farm, 622 Road 2 West	Gosfield South Twp.	542 570

expanded the known range slightly, both eastward and westward. Prior to 1997, the species was not recorded in Kent County or within the Town of Harrow, Essex County. Mole works seen outside Point Pelee National Park during the 1997 field season (Figure 3) are recorded in Table 1. Seemingly suitable sites where mole works were not seen in 1997 are recorded in Table 2.

Macaulay (1980*) noted that, based on a personal communication with S.L. Cumbaa, there is no evidence of the species in any archaeological material unearthed in Canada nor, according to Harrington (1978), any evidence of it from the Quaternary fossil record. Archaeological studies conducted at Point Pelee since 1980 have not produced any material of the species.

Habitat

Dagg (1974) described the habitat of the Eastern Mole in Ontario as meadows, open woodlands, gardens and lawns with moist but well drained soil. Van Zyll de Jong (1983) described the Canadian habitat as soft, moist soils with humus in forests or fields. Banfield (1974) described it similarly as moist, friable loams in open woodlands and pastures. Both van Zyll de Jong and Banfield noted the species' avoidance of gravel and stony soils although

Banfield added that dry sands are avoided. In the U.S. portion of the range, Arlton (1936) and others (Hoffmeister 1989; Gottschang 1981) found the Eastern Mole in a variety of habitats where the soil was sufficiently soft to allow it to be pushed aside during tunnel construction. Jones and Birney (1988) report that, although moist and loose soils are preferred by Eastern Moles in the U.S., all but the driest and hardest substrates, both forested and non-forested, are occupied. In Indiana, Mumford and Whitaker (1982) reported that the species was found in moist habitats, even in areas that were periodically flooded but they found a mole extending a tunnel through "very dry, clay soil in a woods."

In Canada, we found Eastern Mole works most frequently in forested areas and along wooded or brushy hedgerows, watercourses and open drains. In Essex and Kent Counties, Eastern Mole works were not observed in clay or gravelly soils, in very loose, sparsely vegetated sands or in open, shadeless areas. Tunnels were observed to radiate out from shady areas; in some cases, from the shade provided by a single tree or clump of bushes. Tunnels were not seen in cultivated fields except where these were immediately adjacent to hedgerows or other areas with uncultivated soils and in those cases the tunnels only penetrated into the cropland a maximum of



FIGURE 2. Extent of soils suitable as mole habitat in Essex and Kent (now municipality of Chatham-Kent) Counties, Ontario. Locations where Eastern Mole works were observed O and not observed X in 1997.

about three metres. In contrast, Hamilton (1943) states that in the southern United States, cultivated fields are "riddled" with burrows after a rain and, in Illinois, Hoffmeister (1989) found the Eastern Mole in plowed fields. Baker (1983) reports that fertilization and agricultural tillage have improved the mole habitat in southern Michigan and allowed the species to spread. In Canada, Eastern Moles appear to use agriculturally modified habitat infrequently. Outside Point Pelee National Park, the range of the species encompasses a largely agricultural landscape of cash crops (corn, soyabeans, wheat), greenhouses, vegetable crops, orchards, vineyards, and other horticultural crops. The kind of agriculture considered most compatible with the life history of the mole, namely pastureland and hay production, is very limited in Essex County.

During the 1997 fieldwork for this study, Eastern Mole works were observed on the following soil types: Berrien Sand, Berrien Sandy Loam, Brookston Clay Sandspot Phase, Caistor Sand Spot Phase, Eastport Sand, Fox Sandy Loam, Harrow Sand, Harrow Sandy Loam, Plainfield Sand, and Tuscola Fine Sandy Loam (Richards 1989). These

soils can be typified as being stone-free, loose (coarse-textured) and, where topography permits, fast draining. They range from slightly alkaline to moderately acid. Caistor Sand Spot Phase and Brookston Clay Sand Spot Phase are dense, stone-free, clay soils with sandy knolls of variable size and depth overlying the clay. On these soils, moles are restricted to the sandy knolls. The soil types potentially suitable as Eastern Mole habitat in Essex and Kent Counties, Ontario are mapped in Figure 2.

Soil types inhabited by the Eastern Mole in Essex County total 17 400 ha (Richards 1989). The Sand Spot phases of Caistor and Brookston soils total 7890 ha but because only the sandy knolls on these soils provide suitable habitat, the actual amount of habitat contributed by these two soil types is unknown and not included in the 17 400 ha. The latest figures available from the Essex Region Conservation Authority (1992, unpublished) show that 4.2% of Essex County consists of forest and hedgerows suitable for moles. If 4.2% of the suitable soils have the habitat needed by moles, then approximately 1060 ha of natural habitat is theoretically available for mole habitation. This figure is at best a



FIGURE 3. Molehill observed in Kent County (now Municipality of Chatham-Kent), Ontario, 1997, UTM Coordinates: Wheatley 40J/1d 601 790.

very rough estimate for a least three reasons. First, some of the areas with suitable soil are well outside the present range of the mole and will be difficult to colonize. Second, the four townships in Essex County that encompass most of the present range do not have a uniform 4.2% appropriate natural cover. Forest cover data from the Essex Region Conservation Authority for 1992 show Colchester South with 6.56% forest cover (hedgerows not included), Gosfield South with 6.06%, Gosfield North with 1.61% and Mersea with 2.46%. Third, in Canada as elsewhere, moles live in places other than natural habitat; for example, in areas such as cemeteries, manicured parks, orchards, and suburban lawns and gardens.

Clearly, little suitable habitat remains within the Canadian range and what is left exists in a highly fragmented state. There are only 642 woodlands greater than 0.5 ha in Essex County (Essex Region Conservation Authority, unpublished). The natural areas of this region are largely habitat islands surrounded by intensive agriculture. Watercourses in Essex County are often channelized and the woody vegetation removed; nevertheless, moles were observed to use this linking habitat where patches of shade were available. Point Pelee National Park is itself a habitat island for some species — the 4.4 km sand ridge which links it to similar habitat is almost completely developed for permanent and seasonal

housing. If the Eastern Mole population was occupying its present Canadian range prior to settlement by Europeans then it has experienced a great loss of habitat due to forest destruction in the last two centuries.

Population Size

The demography of moles is poorly known. The only comprehensive study of home range for the Eastern Mole was by Harvey (1976) and only twelve individuals were observed in his study. Harvey found that individual ranges overlapped but multiple captures (of different individuals) from a single tunnel system were rare. Harvey observed that established Eastern Moles did not move from their home ranges; although areas might be added to the range, the nest site remained unchanged. He reported that Eastern Moles in Kentucky had home ranges that varied from 1512 to 3430 m² for females and from 3616 to 18041 m² for males.

Gorman and Stone (1990) found that European Moles, *Talpa europaea*, living where food densities were high, occupied small ranges of between 300 to 400 m² whereas moles in areas with low food densities had territories in excess of 5000 m². They also found that male moles expanded their ranges at the beginning of the breeding season. Although the moles in the Gorman and Stone study used overlapping ranges, they used temporal avoidance with only

TABLE 2. Sites where Eastern Mole works were not observed in 1997

Name of Site	Location	UTM Coordinate
Kent County (Chatham-Kent)		Projection Square 40
1. Wheatley Provincial Park	Wheatley	805 604
Essex County		
2. East Mersea Public School	Mersea Twp.	768 600
3. Olinda Unitarian-Universalist Cemetery	Gosfield South Twp.	618 605
4. Kennedy Woods, Jack Miner Sanctuary	Gosfield South Twp.	555 582
5. Ruthven Cemetery	Gosfield South Twp.	639 562
6. Heinz Woods	Leamington	679 555
7. Union Water Plant	Gosfield South Twp.	614 554
8. Kurtz farm	Colchester South Twp.	548 484
9. Oxley Italian Park	Colchester South Twp.	417 495
10. Iler Baptist Cemetery	Gosfield South Twp.	477 511
11. Palen Road Woodlot	Colchester South Twp.	400 511
12. St. Marks Cemetery	Colchester South Twp.	398 516
13. Anderson Woods	Gosfield South Twp.	595 583
14. Bayview Cemetery	Mersea Twp.	686 544
15. Hillman Marsh Conservation Area	Mersea Twp.	768 535
16. Affleck Woods	Colchester South Twp.	430 560
17. Lot 10, Concession III.	Colchester South Twp.	414 575
18. Marentette Beach	Mersea Twp.	767 528
19. Anglican Church Cemetery	Colchester	402 496
20. Fish Point Provincial Nature Reserve	Pelee Island	608 212
21. Brunet Park	LaSalle	312 780
Middlesex County		
22. Strathroy	Caradoc Twp.	481 548
Elgin County		
23. Rodney	Aldorought Twp.	432 134

one individual using the area held in common at any one time.

The estimated sizes of the ranges of individual Eastern Moles are as follows:

- male 1.09 ha, female 0.28 ha (Harvey 1976)
- male 1.0 ha, female 0.3 ha (van Zyll de Jong 1985, apparently based on Harvey 1976)

The densities of moles per hectare have been estimated as follows:

- 20–25 per ha (Jackson 1961)
- 7–12 per ha (Henderson 1983)
- 2–5 per ha (Baker 1983)

Given the above, it appears that densities could vary from 2–25 moles per ha, with the more recent literature favouring a lower density of 2–12 per ha.

Davis and Choate (1993) found a female-biased sex ratio as high as 1:1.8. Females have ranges only 1/3 the size of male ranges and this bias would increase the population density. However, other researchers have reported a male-bias in the sex ratio of: 1.9:1 (Arlton 1936), 1.18:1 (Conaway 1959), and 1.24:1 (Hartman 1992 Ph.D. dissertation as cited in Davis and Choate 1993). A male-biased sex ratio would decrease the density of moles.

Assuming that there are 1060 ha of suitable natural habitat within the Canadian portion of the range, then the Canadian Eastern Mole population living in natural areas will be in the range of 2120–12760

individuals (@ 2–12 moles/ha). Point Pelee National Park with 810 ha of suitable habitat could have a population of between 1620 and 9720 moles. The species has been monitored yearly in the National Park since 1985 along six sampling transects selected on the recommendations of Macaulay (1979*). In April or early May, the number of surface tunnels and pushups along each transect are recorded. Signs of mole activity and therefore, presumably, mole numbers have varied significantly from year to year (Sahanatien and Leggo 1989*). Macaulay (1979*) considered the species common and possibly increasing within Point Pelee National Park.

Macaulay (1980*) noted that moles at Point Pelee are affected by fluctuations in the water table: "Once the tunnels are flooded, both the food supply and habitat of the mole are eliminated. Moles may also be forced to the surface where they become vulnerable to predators..." The water table on Point Pelee is influenced by water levels in Lake Erie which have been rising for the last two centuries and possibly millennia before (Mosquin 1987*). Rising lake levels in the absence of new dune creation and point enlargement will cause a reduction in the mole population at Point Pelee. It is encouraging to note that moles will rapidly colonize natural habitat restoration projects as illustrated by a dune restoration in



FIGURE 4. Sand dune restoration project in Point Pelee National Park colonized by Eastern Moles, 1997. Dominant herbaceous flowering plant is Garlic Mustard, *Alliaria petiolata*.

Point Pelee National Park. Moles occupied this area within three years of the project's completion (Figure 4).

Discussion

The 1997 fieldwork suggests that the Eastern Mole is often present in areas of suitable habitat on the contiguous sand and sandy loam soils in southern Essex County and adjacent Kent County (Figure 2). Twenty-five of the forty six sites examined in this area had evidence of moles (Table 1, Table 2). Based on this fieldwork, the Canadian range of the species has expanded slightly from the range circumscribed in earlier records, but this may be a reflection of greater surveying effort. A significant continued expansion is unlikely because soil types unsuitable for mole habitation lie just outside the present range. About two km of suitable habitat remain uncolonized in the east from the Essex-Kent border to Wheatley Provincial Park and perhaps an additional one km is unoccupied in the west in the Harrow-Colchester area. Suitable soil types in the Ojibway area of Windsor-LaSalle are separated by 20 km of Brookston Clay soil (formerly swamp forest, now drained) and sandy loam soils near Chatham in Kent County are isolated by 30 km of Brookston Clay (Figure 2). No Eastern Moles have been found in either area nor have mole works been seen on Brookstone Clay soils except for the Sand Spot

phase. Saunders' reports for Middlesex and Elgin Counties deserve further study. The Eastern Mole occurs on the mainland of the states of Michigan and Ohio but is not found on any of the islands in Lake Erie although suitable soils are present (Gottshang 1981). This raises the question of the means of dispersal to the Canadian side of Lake Erie.

Yates and Schmidly (1978) state that the fossorial niche tends to limit dispersal and reduce gene flow between populations. The highly fragmented environment available to Eastern Moles in southwestern Ontario and the apparent lack of linkage (increasing with the loss of hedgerows) between many of those habitats should theoretically isolate small populations of moles into demes with restricted genetic exchange. Whether this will result in any deleterious effects such as inbreeding depression remains unstudied. The disjunction, small size and fragmentation of the Canadian population into demes make it an appealing candidate for population genetics studies. Generally speaking, most aspects of mole biology are poorly understood and the literature regarding them fragmented and incomplete (Yates and Pedersen 1982).

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Les Potamogetonaceae du Québec méridional: identification et répartition

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Les 25 espèces présentes au Québec de la famille Potamogetonaceae sont présentées aux moyens de descriptions et de clés dichotomiques. Des cartes de répartition sont fournies pour les 27 espèces et sous-espèces que l'on retrouve dans la partie méridionale de la province. Ces cartes sont accompagnées de commentaires sur l'écologie, l'abondance et l'identification de l'espèce.

Mots clés: Potamogetonaceae, Potamogeton, Stuckenia, carte de répartition, identification, clé dichotomique, Québec, *Potamogeton alpinus*, *P. amplifolius*, *P. bicipulatus*, *P. confervoides*, *P. crispus*, *P. epihydrus*, *P. foliosus*, *P. friesii*, *P. gramineus*, *P. hillii*, *P. illinoensis*, *P. natans*, *P. nodosus*, *P. oakesianus*, *P. obtusifolius*, *P. perfoliatus*, *P. praelongus*, *P. pusillus*, *P. pussillus* sous-esp. *tenuissimus*, *P. pusillus* sous-esp. *gemmiparus*, *P. richardsonii*, *P. robbinsii*, *P. spirillus*, *P. strictifolius*, *P. subsibiricus*, *P. vaseyi*, *P. xhaynesii*, *P. zosteriformis*, *Stuckenia filiformis* sous-esp. *alpina*, *S. filiformis* sous-esp. *occidentalis*, *S. pectinata*.

La famille des Potamogetonaceae compte deux genres au Québec, *Potamogeton* et *Stuckenia*, représentés ensemble par deux douzaines d'espèces largement répandues sur tout le territoire. Mondialement, ces deux genres compte environ une centaine d'espèces (Sorsa 1988). Ce sont des plantes herbacées strictement aquatiques en eau douce ou parfois saumâtre, cosmopolites des régions tempérées. Originaire d'Asie (Les 1983), *Potamogeton* (et *Stuckenia*) serait les genres les plus abondants d'angiospermes dulcicoles (Hutchinson 1975). La famille est considérée récente et spécialisée (Takaso et Bouffman 1984). La difficulté d'accès à leur milieu ainsi qu'une réputation très largement injustifiée de groupe «difficile» font de ces espèces des plantes souvent méconnuées.

Cette méconnaissance de la famille nous est graduellement apparue lors d'explorations floristiques des milieux humides (lacs et rivières, marais, marécages et tourbières) du Bas Saint-Laurent. La première lacune, flagrante, est l'absence de cartes de répartition des espèces pour la province de Québec. Les cartes disponibles couvrent des territoires pour lesquels notre province ne constitue qu'une région périphérique. L'information ainsi véhiculée ne fournit pas de données très précises de la répartition des espèces sur notre territoire. Une seconde lacune qui nous est apparue est l'absence d'outil d'identification de langue française, adapté à notre territoire et reflétant la taxonomie actuellement reconnue de la famille.

Pour combler ces besoins, des cartes de répartition sont présentées pour toutes les espèces et sous-espèces de Potamogetonacées présentes sur le territoire du Québec méridional. Une clé dichotomique d'identification est aussi proposée.

Méthode

Après avoir revu la littérature des Potamogetonaceae d'Amérique du Nord, une clé dichotomique d'identification des espèces fut construite, pour les espèces présentes sur notre territoire.

Tous les spécimens contenus dans les herbiers suivants furent inventoriés: QFA, QUE, MT, CAN, l'Herbier de la Maison mère des Ursulines à Rimouski et l'herbier de l'auteur. Pour certaines espèces les herbiers suivants ont aussi été consultés: DAO, QEF, QFBE, QPAR, MTMG, UQAR, QSA, l'Herbier de la Faculté de Foresterie et de Géodésie de l'Université Laval et enfin l'Herbier du Service canadien de la Faune, bureau régional de Québec. Les inventaires furent effectués en 1990, 1991 et 1992. Les abréviations suivent Holmgren et al. (1990). Au moyen de ces inventaires, des cartes de répartition furent produites pour toutes les espèces présentes au Québec au sud de la latitude 52° nord.

Ces cartes sont accompagnées de quelques commentaires visant à mieux faire connaître l'espèce, souvent en soulignant ses particularités. Ces commentaires ne comprennent pas de description d'espèce. En effet, la clé dichotomique fournie suffisamment d'informations pour distinguer celles-ci et la bibliographie permet d'obtenir des descriptions beaucoup plus précises qu'il ne serait possible de donner ici.

Pour comparer l'abondance réelle des espèces sur le terrain avec les informations obtenues des inventaires d'Herbiers, la présence des espèces a été vérifiée dans 29 plans d'eau du comté de Rimouski, c.-à.- d. 25 lacs ou étangs ainsi que des secteurs de quelques kilomètres de 4 rivières. Pour éviter toute confusion le qualificatif «rare» n'est utilisé que pour

les espèces citées par Bouchard et al (1983) ou Lavoie (1992).

Seuls les synonymes récents pouvant prêter à confusion sont cités. La plupart des espèces, inconnues du public, ne possèdent pas de nom vulgaire. Cependant, lorsque disponible, un nom français (tiré de Marie-Victorin 1997) et un nom anglais (tiré de Gleason et Cronquist 1991) sont mentionnés.

Identification des espèces

Les Potamogetonaceae se distinguent des autres familles de plantes aquatiques par un épi portant plusieurs verticilles de fleurs hermaphrodites, des fruits sessiles ou très courtement pédonculés ainsi que par des feuilles alternes munies d'une stipule dont au moins la ligule est libre.

Une mauvaise opinion n'est certainement pas le moindre des obstacles auxquels se heurte l'identification des Potamogetonacées. Un rapide survol de la littérature fournit de nombreux exemples tels que: «The genus is extremely difficult» (Cronquist et al. 1977), ou bien encore «...(Potamogeton) present considerable difficulties» (Riley 1979). Sculthorpe (1967) quant à lui écrit «... genera of infamous taxonomic repute include *Potamogeton* ...». Fernald (1932) cite Asa Gray qui écrivait «...ignoble Pondweeds...».

La mauvaise réputation que trahissent de tels commentaires est largement surfaite. Il est en effet possible d'identifier facilement un spécimen complet et en bon état, du moins pour les espèces du Québec. De plus, il n'est pas rare que des fragments ou des parties de plante puissent être reliés à un taxon. Avec un peu d'habitude plusieurs espèces peuvent être nommées sur le terrain au premier coup d'oeil.

On ne saurait trop insister sur l'importance d'obtenir des spécimens complets et fructifiés. En effet, le fruit est souvent nécessaire pour nommer sûrement certaines espèces. Comme le font si juste-

ment remarquer Haynes (1974) et Voss (1972), on ne tentera pas de nommer à l'espèce des spécimens à l'état végétatif d'*Aster*, de *Solidago*, de *Panicum* ou encore d'*Habenaria*. Cependant on cherche souvent à nommer un Potamot stérile. C'est très souvent possible mais pas pour tous les groupes. Ceci a entraîné le recours à des caractères végétatifs peu stables, pouvant varier au cours d'une saison de croissance ou selon les conditions du milieu. C'est ainsi que l'on devra être prudent, surtout chez les espèces à feuilles étroites, lors de l'utilisation de la largeur des feuilles, de la forme de la pointe, du nombre de lacunes et de la forme révolutée ou non du bord de la feuille (Haynes 1974). Lorsque la clé a recours au fruit comme critère principal pour distinguer des taxons, il faut être très prudent si l'on nomme un spécimen non-fructifié à partir des critères végétatifs supplémentaires.

Pour qui désire identifier plus sûrement des spécimens atypiques, Ogden (1943) fournit une clé d'identification basée sur l'anatomie de la tige, et ce pour les espèces à feuilles larges. L'anatomie de cette partie de la plante est un critère stable qui n'est pas affecté par les conditions du milieu. Cette méthode est aussi des plus utiles pour la détection des hybrides, la vascularisation de la tige étant alors désorganisée. Nécessitant cependant plus de manipulation ainsi que l'usage d'un microscope, cette façon de faire permet toutefois de souvent régler les cas douteux.

On reconnaîtra un hybride par sa tendance à produire du pollen stérile, par l'absence habituelle de fruits, par la présence de caractères intermédiaires et comme mentionné ci-haut, par une anatomie désorganisée de la tige.

La longueur d'un fruit est mesurée sans le bec. Le fruit doit être mûr. Noter particulièrement la présence ou l'absence d'une carène sur le dos du fruit. Cette carène pourra être ailée ou non.

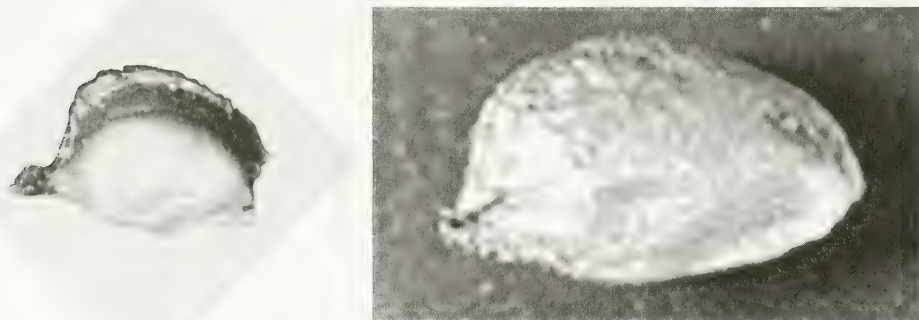


FIGURE 1. Fruit de *P. foliosus* portant une carène ailée et fruit de *P. natans* à dos lisse.

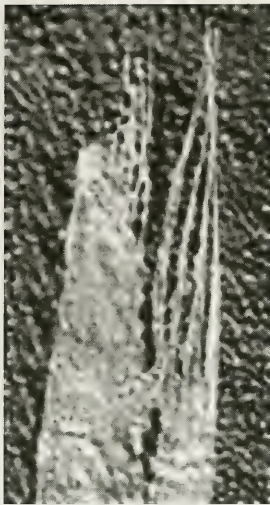


FIGURE 2. Stipule fibreuse de *P. friesii*.

Il faut observer les feuilles submergées du milieu de la tige. Se méfier particulièrement des feuilles de la partie supérieure de la tige qui peuvent être de forme intermédiaire avec les feuilles flottantes, si ces dernières sont produites.

Il faut observer les stipules à la base des jeunes feuilles submergées. Les feuilles plus vieilles de la base de la tige ont souvent des stipules déchirées et en mauvais état. Les stipules des feuilles flottantes

ne sont pas utilisées. Observer si elles sont fibreuses (figure 2) ou plutôt membraneuses et plus ou moins herbacées.

Un critère fondamental est le mode d'insertion de la stipule sur la tige. Est-elle directement insérée à l'aisselle de la feuille ou forme-t-elle une gaine à la base de cette feuille, entourant la tige sur une certaine longueur ?

Pour déterminer si une stipule est connée ou convolutive, observer des sections faites dans la partie jeune d'une branche fraîche ou réhydratée. Les stipules connées encercleront sans interruption la tige. Elles peuvent cependant se briser avec l'âge et ainsi paraître convolutées. Lorsqu'il faut évaluer la couleur des stipules, se méfier de la présence de dépôts, de planctons ou d'algues pouvant en modifier la teinte.

Pour préparer des spécimens d'herbiers intéressants, utiliser un bac contenant juste assez d'eau pour faire flotter le spécimen. Placer une feuille de papier journal taillée à la dimension d'un carton d'herbier au fond du bac. Déployer le spécimen par-dessus la feuille puis retirer la feuille en la glissant dans l'eau par une extrémité et laisser égoutter. Laisser le spécimen sur cette feuille pour le séchage. Appliquer à la presse de séchage le minimum de pression pour que les feuilles gardent leur forme tout en évitant de trop aplatir la tige. Après séchage, séparer délicatement la plante du papier journal. Les dépôts calcaires souvent présents sur les plantes se détacheront aisément d'eux-mêmes après séchage.

Clé artificielle d'identification des Potamogetonacées du Québec.

- 1) Feuilles submergées présentant 9-18 rangées de cellules lacunaires de part et d'autre de la nervure centrale, formant une bande distincte occupant le quart ou le tiers de la largeur de la feuille (ne pas confondre avec la région réticulée présente chez certaines autres espèces). Tige comprimée, feuilles à marges parallèles, larges de 2-10 mm, molles, distiques. *P. epihydrus* (3)
- 1) Feuilles submergées sans cellule lacunaire de part et d'autre de la nervure centrale ou si présentes alors moins de 6 rangées de cellules et ne formant pas une zone pâle distinctement délimitée; les autres caractères différents. (2)
- 2) Stipules des feuilles submergées adnées au limbe de la feuille, formant une gaine entourant la tige, le limbe ou le pétiole de la feuille prenant naissance de cette gaine. Pointe de la stipule projetant et formant une ligule. (Groupe A)
- 2) Stipules distinctes des feuilles submergées, le pétiole ou le limbe de la feuille directement attaché à un noeud de la tige. (3)
- 3) Feuilles submergées à marges parallèles, étroites, linéaires, sessiles. Si linéaires à marges non parallèles, alors la plante (mature) est munie de feuilles flottantes coriaces bien développées. (Groupe B)
- 3) Feuilles submergées à marges non-parallèles, lancéolées, ovales, oblongues ou de formes intermédiaires, sessiles ou pétiolées. (Groupe C)

Groupe A: Espèces à feuilles submergées étroites et à stipule adnée au limbe.

- 1) Fruits latéralement aplatis, munis d'une carène dorsale. Feuilles flottantes généralement présentes. Stipules longues de 2-12 mm. Feuilles submergées étroites et arquées. *P. spirillus* (3)
- 1) Fruits à dos lisse, sans carène. Feuilles flottantes absentes. (2)
- 2) Feuilles larges de (2.5)3-8(9) mm, munies de 20-40 nervures, munies sur le bord d'une bande cartilagineuse pâle, auriculées à la base, linéaires, souvent rigides, distiques, donnant ainsi à la plante un aspect en forme de plume. Stipules pâles. Extrémité de la ligule divisée et formant deux pointes. Fruits très rares. *P. robbinsii*
- 2) Feuilles jusqu'à 2(2.5) mm de large, munies de 1-5(7) nervures. *Stuckenia* (3)

- 3) Extrémité des feuilles aiguës; fruits longs de (2,5)3-4.5 mm. Stigmate sur un style court, incurvé sur la face ventrale du fruit et persistant en fruit pour former un bec; épi muni de 5-12 verticilles de fleurs. *S. pectinata*
- 3) Extrémité des feuilles obtuse, souvent munie d'un sinus ou courtement apiculée; fruits longs de 2-3 mm. Stigmate sessile; épi muni de 2-6 verticilles de fleurs. *S. filiformis*

Groupe B: Espèces à feuilles submergées étroites et à stipule non adnée au limbe.

- 1) Feuilles flottantes présentes (chez les individus matures). (2)
- 1) Feuilles flottantes absentes. (4)
- 2) Feuilles flottantes longues de 0.8-1.5 cm, feuilles submergées longues de 2-6 cm; épis longs de 3-8 mm. *P. vaseyi*
- 2) Feuilles flottantes longues de 1.5-12 cm, feuilles submergées longues de plus de 5 cm; épis longs de 10-50 mm. (3)
- 3) Pétioles des feuilles flottantes marqués d'une bande pâle et blanchâtre à la base du limbe de la feuille; feuilles submergées phyllodiales, semi-cylindriques et devenant étroitement aiguës à la pointe, 0.8-2.0 mm de large. Tige 0.8-2 mm de diamètre. Feuilles flottantes cordées à la base chez les individus matures *P. natans*
- 3) Bande pâle absente; feuilles submergées étroitement linéaires et obtuses, 0.25-1 mm de large. Tige 0.5-1 mm de diamètre. Feuilles flottantes cunéaires ou atténuées à la base. *P. oakesianus*
- 4) Feuilles munies de plus de 9 nervures. (5)
- 4) Feuilles munies de 7 nervures ou moins. (6)
- 5) Tige arrondie; feuilles 1.5-2 mm de large, munies de 9-17 nervures, fruits longs de 3-4 mm, munis d'un bec central long de 0.3-0.5 mm. *P. subsibiricus*
- 5) Tige très aplatie, souvent ailée, feuilles 2-5 mm de large, munies de 15-35 nervures, fruits longs de 4-5 mm, munis d'un bec latéral long de 0.6-1 mm. *P. zosteriformis*
- 6) Surface dorsale du fruit muni d'une carène ailée. (7)
- 6) Surface dorsale du fruit lisse et arrondie, sans carène. (8)
- 7) Inflorescence cylindrique, longue de 8 mm. Glandes axillaires habituellement présentes, d'un diamètre de 0.5 mm ou plus. Feuilles souvent rougeâtres, à l'extrémité arrondie, obtuse ou apiculée. Fruits longs de 2.5-3.6 mm. *P. obtusifolius*
- 7) Inflorescence capitée, longue de 1.5-7 mm. Glandes axillaires peu fréquentes, d'un diamètre de 0.3 mm. Feuilles aiguës ou apiculées, vertes ou olive. Fruits longs de 1.5-2.7 mm. *P. foliosus*
- 8) Pédoncules allongés, (5-)10-25 cm, feuilles filiformes, larges de 0.1-0.5 mm, uninervées. *P. confervoides*
- 8) Pédoncules plus courts ou absents. (9)
- 9) Stipules fibreuses et blanchâtres; pédoncules claviformes. (10)
- 9) Stipules délicates, non-fibreuses, blanchâtres, brunâtres ou verdâtres; pédoncules cylindriques. (11)
- 10) Feuilles intérieures des hibernacles en éventail, courtes et ondulées, à angle droit des feuilles externes qui sont allongées; feuilles de la tige avec 5-7 nervures et à l'extrémité arrondie ou apiculée. *P. friesii*
- 10) Hibernacles fusiformes; feuilles de la tige trinervées à l'extrémité, se terminant en pointe. *P. strictifolius*
- 11) Fruits longs de 2.5-3.6 mm, larges de 1.7-2.4 mm; hibernacles longs de 3.5-7.8 cm, larges de 2.3-5.1 mm, feuilles intérieures non-modifiées; feuilles souvent rougeâtres, à l'extrémité arrondie, obtuse ou apiculée. *P. obtusifolius*
- 11) Fruits longs de 1.5-2.2 mm, larges de 1.2-1.6 mm; hibernacles longs de 0.9-3.2 cm, larges de 0.3-1.8 mm, feuilles intérieures regroupées en une structure fusiforme; feuilles olive ou vertes à l'extrémité obtuse, aiguë ou apiculée. *P. pusillus*

Groupe C: Espèces à feuilles submergées larges.

- 1) Feuilles submergées à marges fortement ondulées et dentées, fruits munis d'un bec de 2-2.5 mm Tige aplatie. *P. crispus*
- 1) Feuilles submergées à marges peu ou pas ondulées, si dentées, les dents minuscules et évanescents. Bec du fruit moins de 1.5 mm Tige aplatie ou arrondie. (2)
- 2) Feuilles submergées amplicaulées. Feuilles flottantes absentes. (3)
- 2) Feuilles submergées sessiles ou pétiolées, n'embrassant pas la tige. Feuilles flottantes absentes ou présentes. ... (5)
- 3) Feuilles longues de (5-)10-20(-25) cm, à l'extrémité cucullée (chez les spécimens d'herbier aplatis par le pressage, l'extrémité est fendue longitudinalement de façon caractéristique); fruits longs de 4-5.7 mm, munis d'une carène aiguë. Rhizome marqué de points rouges. Pédoncules jusqu'à 6 dm de long. *P. praelongus*
- 3) Feuilles longues de 1-10 cm, à l'extrémité plate, fruits longs de 1.6-4.2 mm, obscurément carénés; pas de points rouges sur le rhizome. Pédoncules jusqu'à 2.5 dm de long. (4)
- 4) Endocarpe percé d'une cavité (couper le fruit longitudinalement); stipules à texture grossière, se désintégrant et laissant des fibres blanchâtres et persistantes, fruits longs de 2.2-4.2 mm Feuilles ovées-lancéolées à étroitement lancéolées, longues de (3-)5-12 cm, munies de 13 à 21 nervures principales coriaces. Pédoncules pouvant atteindre 25 cm. *P. richardsonii*
- 4) Endocarpe plein; stipules délicates et évanescents, fruits longs de 1.6-3 mm. Feuilles orbiculaires à ovées-lancéolées, longues de 1-6 cm, munies de 7 à 21 nervures délicates. Pédoncules pouvant atteindre 10 cm. *P. perfoliatus*

- 5) Stipules des feuilles submergées longues de 4-10 cm, feuilles submergées munies de 7-37 nervures. (6)
- 5) Stipules des feuilles submergées longues de 1-3 cm, feuilles submergées munies de 3-9 nervures principales, sessiles. (8)
- 6) Feuilles submergées principales fortement falquées, pliées longitudinalement, munies de 23-37 nervures; fruits longs de 4-5.5 mm. *P. amplifolius*
- 6) Feuilles submergées non falquées et pliées, munies de 7-19 nervures; fruits longs de moins de 4 mm. (7)
- 7) Feuilles submergées principales larges de 1-2.5(-3) cm munies d'un pétiole de (2-)-5-13 cm. Fruits longs de 3.5-4 mm, à carène tuberculée. *P. nodosus*
- 7) Feuilles submergées principales larges de 2-5 cm, sessiles ou munies d'un pétiole de 2-5 cm. Fruits (2.5-)2.7-3.5 mm, carène unie. *P. illinoensis*
- 8) Feuilles submergées à extrémité obtuse ou aiguë, étroitement lancéolées (atténuées à partir de la base) longues de (4.5-) 8-14(-20) cm, se teintant souvent de rouge au séchage, particulièrement dans la région réticulée près de la nervure principale. Feuilles flottantes (si présentes) à base cunéaire, sans distinction marquée entre le limbe et le pétiole. Stipules obtuses; 3 ou 4 fruits pédicellés par fleur, à parois dures, lisses et arrondies, longs de (2.5-) 3-3.5 mm. Tige habituellement simple. *P. alpinus*
- 8) Feuilles submergées à extrémité aiguë ou mucronée, elliptiques-lancéolées (atténuées à chaque extrémité) longues 1-9(-13) cm. Feuilles flottantes à base atténuée, munies d'un pétiole bien distinct. Stipules aiguës; 1 ou 2 fruits non pédicellés par fleur, à parois spongieuses, comprimés, longs de 1.7-2.5(-2.8) mm. Tige souvent ramifiée *P. gramineus*

Abondance au Québec

Pour illustrer l'abondance de chaque espèce sur le territoire québécois, la figure 3 montre le pourcentage respectif de chaque espèce du nombre total des spécimens de Potamogetonacées conservés aux herbiers CAN, MT, QFA et QUE. Les récoltes provenant d'une même localité n'ont pas été discriminées, le but étant d'obtenir une qualification de l'abondance relative des espèces plutôt qu'une quantification des individus ou des populations.

Les 9 taxons de la partie supérieure du graphique sont les espèces et sous-espèces qualifiées ici d'occasionnelles, chacune d'elles représentant moins de 1% des spécimens en herbier. C'est évidemment dans ce groupe que se rencontreront les espèces rares au Québec. Les 9 taxons de la partie inférieure sont les espèces et sous-espèces qualifiées d'abondantes sur le territoire. De ce nombre, 7 sont clairement ubiquistes (voir plus bas). Les taxons intermédiaires peuvent être localement abondants ou dispersés sur le territoire.

Répartition géographique des espèces au Québec

L'interprétation des cartes présentées ici est compliquée par le fait que nous avons affaire à des plantes de milieu aquatique. Comme on pouvait s'y attendre, la corrélation entre la répartition des espèces avec les régions écologiques du Québec (Thibault 1985) est au mieux très grossière. Les milieux aquatiques sont azonaux et leur végétation est affectée de façon différente par le nombre de degrés-jours de croissance. En effet, la plus grande uniformité du régime thermique du milieu aquatique permet la dispersion des espèces aquatiques à travers les différents domaines écologiques.

D'autre part, Hellquist (1975 et 1980) a établi, pour les espèces de la Nouvelle-Angleterre, que le facteur présentant la plus forte corrélation avec la répartition des Potamogetons est l'alcalinité totale de

l'eau dans laquelle croissent ces espèces. Dans ces études, l'auteur regroupe les espèces en six groupes selon leur affinité pour les carbonates.

Il semble possible d'expliquer la répartition de la plupart des espèces sur le territoire québécois de manière analogue. Aussi, ce classement est-il repris ici et adapté à nos espèces.

Le tableau original a été modifié pour regrouper les variétés d'une même espèce qu'il n'a pas été jugé utile de distinguer sur les cartes et dans la clé. Lorsque ces variétés se retrouvaient dans des groupes différents, l'espèce ainsi reconstituée est placée dans un groupe intermédiaire. Les valeurs d'alcalinité indiquées représentent des valeurs moyennes pour l'ensemble des plans d'eau où l'espèce fut récoltée.

Groupe I - alcalinité moyenne:

0,0-18,3 mg HCO₃⁻/litre

P. confervoides

P. oakesianus

P. pusillus sous-esp. *gemmaiparus*

Groupe II - alcalinité moyenne:

18,4-30,5 mg HCO₃⁻/litre

P. spirillus

P. vaseyi

P. robbinsii

Groupe III - alcalinité moyenne:

30,6-48,8 mg HCO₃⁻/litre

P. amplifolius

P. perfoliatus

P. pusillus sous-esp. *tenuissimus*

P. epihydrus (variétés regroupées)

P. gramineus (variétés regroupées)

P. alpinus (variétés regroupées)

P. natans

Groupe IV - alcalinité moyenne:

48,9-73,2 mg HCO₃⁻/litre

P. richardsonii

P. praelongus

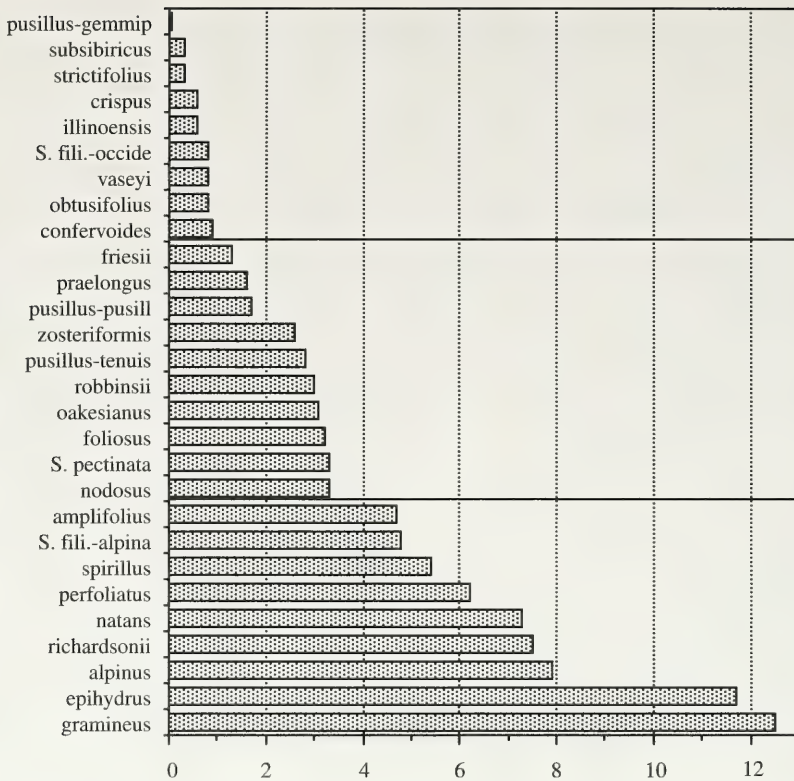


FIGURE 3. Pourcentage respectif du nombre total de spécimens de chaque taxons de Potamogetonacées conservés aux quatre principaux herbiers inventoriés.

P. obtusifolius
P. zosteriformis

Groupe V - alcalinité moyenne:

73,3-109,8 mg HCO_3^- /litre
P. pusillus sous-esp. *pusillus*
P. foliosus
S. filiformis sous-esp. *alpina*
P. illinoensis
P. strictifolius
P. crispus
P. friesii
P. nodosus

Groupe VI - alcalinité moyenne:

> 109,8 mg HCO_3^- /litre
S. pectinata

Les espèces présentant des répartitions similaires au Québec ont aussi été regroupées. Pour chacune d'entre elles le lien est fait avec les groupes de Hellquist. On a aussi tenté de situer, lorsque possible, ces aires de répartition par rapport aux régions écologiques du Québec (Thibault 1985).

Lorsque l'on étudie la répartition d'espèces entièrement aquatiques comme c'est ici le cas, il est

important de garder présent à l'esprit les remarques précédentes sur les milieux azonaux. Des mentions d'une espèce peuvent se situer très loin de son aire principale de répartition. Ces stations périphériques doivent être expliquées par les conditions locales. Il est souvent nécessaire d'ignorer de telles stations disjointes pour mieux cerner la répartition d'une espèce.

Regroupement des Potamogetonacées du Québec selon leurs types de répartition:

Les espèces ubiquistes

Il est assez remarquable que toutes les espèces du groupe III de Hellquist soient ubiquistes au Québec, confirmant qu'elles peuvent s'adapter à toute la gamme des valeurs d'alcalinité. Ces espèces se divisent en deux sous-groupes.

Les espèces ubiquistes sur tout le territoire. Ce sont aussi les espèces les plus abondantes, d'après la figure 3. Il s'agit des espèces: *P. epihydrus*, *P. gramineus* et de *P. alpinus*.

Les espèces ubiquistes au sud du 49° de latitude nord : Remarquons que cette latitude correspond grossièrement au passage de la forêt mixte à la forêt coniférienne (ou boréale), selon Thibault (1985). Ces

espèces sont aussi très abondantes. Il s'agit de: *P. spirillus*, *P. amplifolius*, *P. natans*, *P. perfoliatus* et de *P. pusillus* sous-esp. *tenuissimus*. Le 49° parallèle est indiqué sur les cartes de ces cinq espèces.

Les espèces de milieux acides

C'est le groupe le plus restreint. Il ne comporte que deux espèces, chacune présentant une répartition très particulière sur notre territoire: *P. confervoides* et *P. oakesianus*.

Les espèces disjointes d'affinité calcaire

De façon générale ces espèces sont absentes ou très occasionnelles des régions du bouclier canadien. Ailleurs au Québec, elles présentent une répartition disjointe. En effet elles sont présentes dans le Sud-Ouest de la province, dont il sera question plus bas, et dans le Bas Saint-Laurent/Gaspésie incluant parfois les régions du Golfe. Ces deux régions sont séparées par une zone d'où ces espèces sont absentes ou très peu abondantes. A une exception près, il s'agit des espèces d'affinité calcaire des groupes IV, V et VI de Hellquist.

Les espèces typiques de ce groupe sont, selon leur abondance: Les espèces disjointes abondantes: *P. praelongus*, *P. zosteriformis*, *P. foliosus* et *P. pusillus* sous-esp. *pusillus*. Les espèces disjointes occasionnelles: *P. strictifolius*, *S. filiformis* sous-espèce *occidentalis* et *P. friesii*.

Deux espèces présentent une répartition très particulière et peuvent former un sous-groupe. *S. pectinata*

et *S. filiformis* var. *alpina* sont présents dans le Sud-Ouest principalement dans le fleuve Saint-Laurent alors que les populations de l'Est sont de répartition plus générale.

Les espèces du Sud-Ouest

Ce sont les espèces limitées aux Basses Terres du Saint-Laurent et de l'Outaouais. Ce sont les régions les plus chaudes du Québec. Il s'agit de trois espèces du groupe V et assez curieusement d'une espèce du groupe II. Ces espèces sont: *P. vaseyi*, *P. illinoensis*, *P. nodosus* et *P. crispus*. Cette partie du Québec constitue une extension dans notre province des régions floristiques du nord-est des États-Unis et du sud de l'Ontario où ces espèces sont plus abondantes.

Espèce boréale

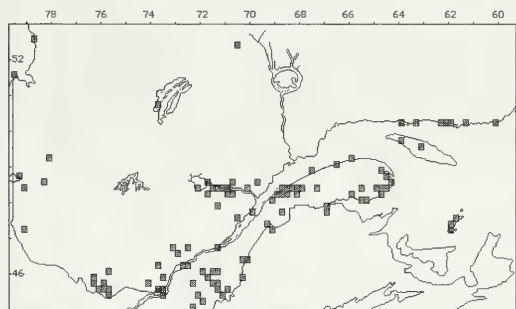
Une seule espèce est uniquement subarctique sur notre territoire. Il s'agit de *P. subsibiricus*.

L'effort d'herborisation au Nouveau-Québec étant loin d'égaliser celui des régions méridionales, les régions les plus nordiques de la province ne sont pas couvertes par les cartes. Cependant, sous le traitement de chaque espèce il est indiqué si celle-ci est connue au Nouveau-Québec.

Enfin une espèce, *P. pusillus* sous-esp. *gemmiparus* est trop peu abondantes pour tenter de l'incorporer à l'un de ces groupes. Trois autres espèces présentent des répartitions particulières qui seront discutées sous chacune. Il s'agit de: *P. obtusifolius*, *P. robbinsii* et *P. richardsonii*.

Cartes de répartition

(1) *Potamogeton alpinus* Balbis [Potamot alpin, Red Pondweed]



CARTE 1. *Potamogeton alpinus*.

Cette espèce est ubiquiste au Québec et est classée dans le Groupe III de Hellquist. Elle affectionne les endroits peu profonds où elle peut trouver de l'eau claire et calme et un fond de fine vase organique. On la trouve typiquement dans les petites anses ou bras le long des lacs ou des cours d'eau. Puisqu'elle croît sur des fonds peu fermes, il est très facile d'obtenir les parties souterraines lors des récoltes. La plante peut être déroutante car elle montre une grande plas-

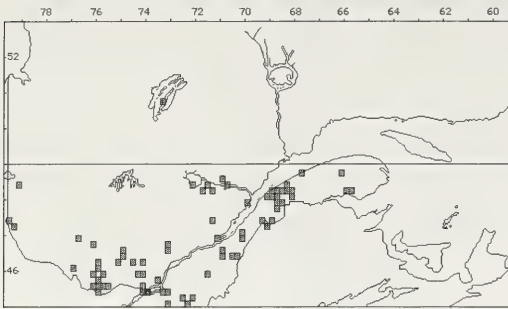
titude de forme, liée à son milieu de croissance. Arrivée à maturité en eau peu profonde, elle peut présenter plusieurs paires de feuilles flottantes à l'extrémité d'une tige sans feuilles submergées. Par contre, en eau profonde ou si elle est encombrée par d'autres plantes, les feuilles flottantes peuvent être absentes. C'est l'une des espèces qui développent régulièrement des feuilles intermédiaires entre les feuilles flottantes et les feuilles submergées.

Les feuilles flottantes cunéaires et, après séchage, l'aspect rougeâtre et réticulé des feuilles submergées serviront à mettre sur la piste lors de l'identification.

Potamogeton alpinus a été subdivisée en deux variétés par Ogden (1943) sur la base de la forme et du rapport longueur/largeur des feuilles submergées: var. *tenuifolius* (Raf.) Ogden et var. *subellipticus* (Fern.) Ogden. Ces distinctions ne sont pas retenues ici, en accord avec l'opinion de Hellquist et Crow (1980). En effet, des spécimens intermédiaires entre ces variétés se rencontrent assez fréquemment, parfois même des individus portant les deux types de feuilles.

Répartition globale: Circumboréale. Présent au Nouveau-Québec.

(2) *Potamogeton amplifolius* Tuckerm. [Potamot à feuilles larges, Big-leaved Pondweed]



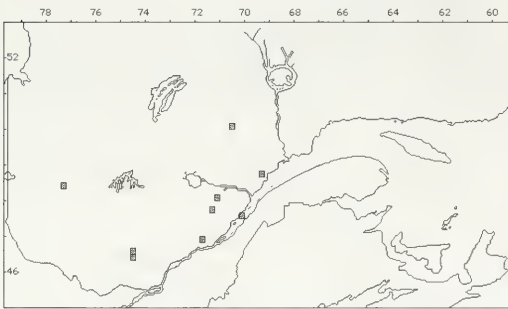
CARTE 2. *Potamogeton amplifolius*.

Potamogeton amplifolius est ubiquiste au sud du 49° parallèle et est classé dans le Groupe III de Hellquist.

C'est notre plus grande espèce. La forme arquée de ses grandes feuilles submergées l'identifie à coup sur du premier coup d'oeil. Typiquement, elle se rencontre en petites colonies plus ou moins circulaires en eaux profondes à quelque distance du rivage, parfois même jusque dans la zone le l'infra littoral inférieur. Ces individus submergés en eaux profondes ne développent pas de feuilles flottantes. Cependant, si ces feuilles submergées atteignent la surface elles laissent échapper à l'atmosphère une hormone jusqu'alors retenue par la pression hydrostatique. Cette hormone inhibitrice disparue, la croissance de feuilles flottantes est initiée (Sculthorpe 1967). Sa répartition n'atteint pas le Nouveau Québec et la plante n'est vraiment abondante que dans le sud et l'ouest de la province.

Répartition globale: Amérique du Nord.

(3) *Potamogeton confervoides* Reincheb. [Alga Pondweed]



CARTE 3. *Potamogeton confervoides*.

Cette espèce du Groupe I de Hellquist présente une répartition unique chez les Potamots du Québec:

l'espèce est présente uniquement au nord du Saint-Laurent sans atteindre les latitudes nordiques. *P. confervoides* est le plus acidiphile des Potamogetons nord-américains (Hogdon et al. 1952; Hellquist 1975 et 1980), ce qui explique sa complète absence des régions calcaires du Québec.

Le port des individus fertiles distingue cette espèce de tous nos autres Potamots. La tige abondamment ramifiée et portant de nombreuses petites feuilles linéaires contraste avec le grand pédoncule qui semble disproportionné. A l'état végétatif cependant, elle peut facilement passer inaperçue ou être confondue avec d'autres espèces vasculaires. Ceci laisse soupçonner que l'abondance réelle de l'espèce est probablement sous-estimée. *P. confervoides* est l'une des plantes rares du Québec (Bouchard et al. 1983).

Répartition globale: Nord-est de l'Amérique.

(4) *Potamogeton crispus* L. [Potamot crispé, Curly Pondweed]



CARTE 4. *Potamogeton crispus*.

Espèce du Groupe V de Hellquist, c'est le seul de nos Potamots qui soit introduit. C'est une espèce souvent envahissante et qui se comporte en mauvaise herbe (Spicer et Catling 1990). Elle est abondante dans le sud de l'Ontario (Catling et Dobson 1985) alors qu'au Québec elle se cantonne dans l'extrême sud-ouest sans vraiment être problématique. C'est une espèce qui peut tolérer les eaux polluées et elle peut s'établir dans les zones à fort courant. Elle recherche les substrats fermes.

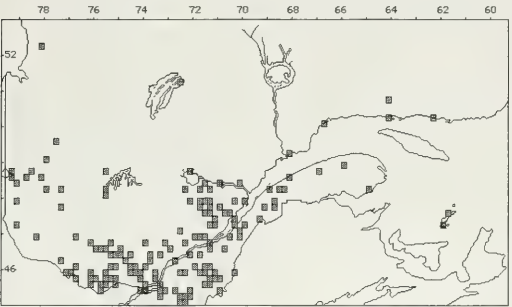
Le mode de reproduction asexuée de cette espèce est assez particulier. Au printemps, des boutures sont produites abondamment. Au milieu de l'été, celles-ci

et les fruits mûrs se détacheront simultanément de la plante qui meurt alors. A l'automne, alors que la végétation aquatique disparaît, ces boutures, qu'on ne peut donc pas nommer hibernacles, germent et produisent de nouveaux individus qui seront matures au tout début de la saison suivante de végétation, avant les autres espèces (Catling et Dobson 1985). Les fruits de l'espèce germent très peu ou pas du tout.

Potamogeton crispus joue un rôle important dans l'alimentation des oiseaux aquatiques et des invertébrés recherchés par les poissons (Catling et Dobson 1985).

Répartition globale: Originaire d'Europe, maintenant cosmopolite.

(5) *Potamogeton epihydrus* Raf. [Potamot émergé, Ribbonleaf Pondweed]



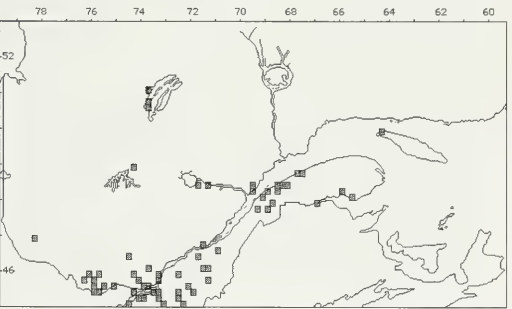
CARTE 5. *Potamogeton epihydrus*.

Potamogeton epihydrus est l'une des espèces très ubiquistes sur tout notre territoire (Groupe III de Hellquist). Comme *P. gramineus*, cette espèce s'acclimate à presque toutes les conditions. Elle arrive en deuxième position au Québec pour l'abondance.

La large bande lacunaire de couleur pâle au centre des feuilles submergées permet d'identifier facilement cette espèce. Certains auteurs (Voss 1972; Ogden 1974; Hellquist 1980) distinguent deux variétés sur la base des dimensions des feuilles submergées et des fruits: var. *epihydus* et var. *ramosus* (Peck) House. Tous ces auteurs mettent cependant en garde contre la gradation des caractères utilisés. Comme Gleason et Cronquist (1991) et Cronquist et al. (1977), ces variétés ne sont pas retenues ici. En effet, des individus intermédiaires entre ces deux variétés se rencontrent souvent. De plus, les individus d'une population du comté de Rimouski, qui pourraient être clairement de la variété *epihydus* par leurs grandes dimensions, montraient une désorganisation de l'anatomie interne de la tige habituellement notée chez les hybrides.

Répartition globale: Amérique du Nord. Présent au Nouveau-Québec. Synonyme: *P. epihydrus* var. *nuttallii* (C.&S.) Fern.

(6) *Potamogeton foliosus* Raf. sous-esp. *foliosus* [Potamot feuillé, Leafy Pondweed]



CARTE 6. *Potamogeton foliosus* sous-esp. *foliosus*.

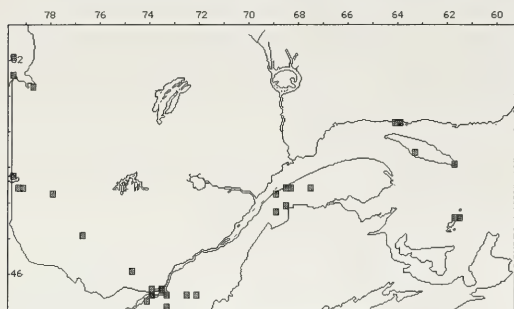
Espèce d'affinité calcaire (Groupe V de Hellquist) à répartition disjointe, la plante est localement abondante dans son territoire. Le Bas Saint-Laurent constitue la limite de son abondance vers l'Est. Cette espèce, bien qu'indigène, se com-

porte souvent en mauvaise herbe par son aptitude à coloniser rapidement et abondamment les milieux artificiels.

La pollinisation est hydrophile et la plante fructifie abondamment à l'aisselle des branches. Sa petite taille et son fruit caréné en font une espèce facile à identifier.

À l'état végétatif cependant, l'identification est beaucoup plus hasardeuse. En effet, l'espèce pourrait facilement être confondue avec *P. pusillus*. Selon Haynes (1974) la variété *tenuissimus* peut être distinguée par les bandes lacunaires plus nombreuses des feuilles. La variété *pusillus* quant à elle pourrait être distinguée par le fait que les nervures des stipules sont pratiquement indiscernables alors qu'elles sont distinctes jusqu'à l'extrémité de la stipule chez *P. foliosus*.

Répartition globale: Amérique du Nord et Centrale. Présent au Nouveau-Québec. Synonymie: *P. foliosus* Raf. var. *macellus* Fern.

(7) *Potamogeton friesii* Rupr. [Potamot de Fries, Fries' Pondweed]CARTE 7. *Potamogeton friesii*.

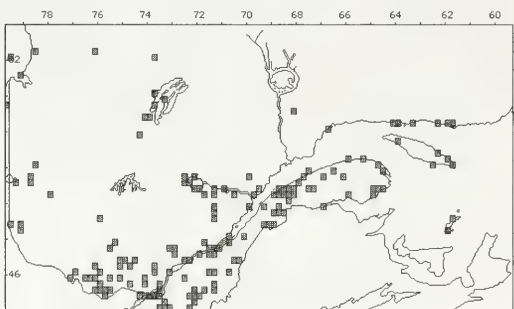
Potamogeton friesii est classé dans le Groupe V de Hellquist. L'espèce est très calciphile et présente une répartition disjointe sur notre territoire. Dans les régions où elle est présente, l'espèce est dispersée et

peu abondante. *P. friesii* est intolérant à la pollution (Haynes 1974). Notons que *P. strictifolius* présente des caractéristiques tout à fait similaires.

Cette délicate espèce à feuilles étroites et toutes submergées possède un cycle de reproduction entièrement hydrophile, les épis restant toujours submergés. La plante produit très abondamment les hibernacles qui sont si caractéristiques de l'espèce. En fait, la plupart des spécimens, bien que fertiles, semblent s'être régénérés à partir de ces structures. Ceci jette un doute sur la part de la reproduction sexuée dans le maintien des populations. Cependant, voir la remarque sous *P. pusillus* à ce sujet.

Les individus sont souvent très ramifiés et croissent en groupes serrés. Il s'agit certainement de notre plus belle espèce, formant de superbes «bouquets» sous-marins d'un vert pastel.

Répartition globale: Amérique du Nord.

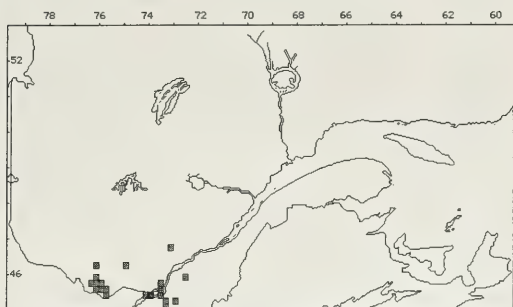
(8) *Potamogeton gramineus* L. [Potamot graminioïde, Variable Pondweed]CARTE 8. *Potamogeton gramineus*.

Notre espèce la plus abondante, elle est absolument ubiquiste dans tout le Québec. Faisant partie du groupe III de Hellquist, l'espèce s'installe dans tous les types de plan d'eau: eaux calcaires ou acides, lac eutrophisé ou oligotrophe, étang calme, lac agité par les vagues ou lit de rivière, sur des fonds grossiers de gravier ou sur de fine vase organique, sous quelques centimètres ou plusieurs mètres de profondeur. C'est une espèce qui formera des rosettes de feuilles aériennes pour résister à l'assèchement de son plan d'eau. L'espèce est présente dans 93% des plans d'eau du comté de Rimouski et représente 12,5 %

des spécimens de *Potamogeton* des herbiers inventoriés.

Cette espèce semblera protéenne à qui la rencontrera la première fois. Toutefois, les stipules courtes et les feuilles submergées sessiles et aiguës sont des caractères stables indiquant cette espèce. *P. gramineus* est une espèce chez qui il est aisé d'observer l'effet de la profondeur d'eau disponible sur le port de la plante. En eaux très profondes se retrouvent des spécimens à tige unique, sans ramification et à grandes feuilles très espacées. Dans quelques centimètres de profondeur, on trouve typiquement des individus couchés et buissonnants, à petites feuilles rapprochées. Ces formes, liées aux conditions du milieu, sont probablement à l'origine de la division de l'espèce en plusieurs variétés sans grande valeur phylogénique. Ces variétés encore parfois rencontrées dans la littérature sont: var. *gramineus*, var. *maximus* Morong et var. *myriophyllus* Robbins. La distinction se ferait sur la base de la dimension, la forme et la nervation des feuilles submergées. *P. gramineus* est de plus bien connu pour former des hybrides avec la plupart des espèces à larges feuilles et même avec certaines espèces à feuilles étroites (Hellquist 1978).

Répartition globale: Circumboréale. Présent au Nouveau-Québec.

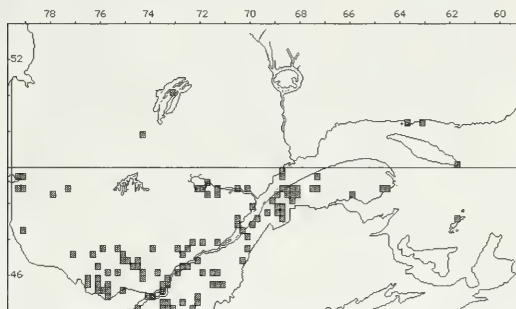
(9) *Potamogeton illinoensis* Morong. [Potamot de l'Illinois, Illinois' Pondweed]CARTE 9. *Potamogeton illinoensis*.

Potamogeton illinoensis est une espèce rare au Québec (Bouchard 1983; Lavoie 1992). Elle n'est connue que des régions les plus chaudes de l'extrême sud-ouest de la province où elle pénètre en

provenance de son aire principale au sud des Grands Lacs et en Nouvelle-Angleterre (Ogden 1943). C'est une espèce du Groupe V de Hellquist. La station située au nord-ouest de Trois-Rivières par 46°49' N. 073°07' O. représente la limite nordique de la répartition québécoise de la plante. Au sud du Saint-Laurent, elle n'est pas connue au nord-est de la rivière Saint-François à la hauteur de Drummondville.

Cette espèce peut être confondue avec *P. nodosus* et *P. gramineus*, avec lesquels elle hybride facilement, ajoutant ainsi à la confusion. L'histoire tourmentée de la taxonomie de cette espèce (Ogden 1943) est un reflet de la variabilité de l'espèce. La difficulté est accrue par le fait que *P. illinoensis* soit fréquemment récolté en rivière où il est notoire que le courant affecte le port et la morphologie des Potamogetons. Les individus qui ne développent pas de feuilles flottantes sont nombreux.

Répartition globale: Amérique du Nord.

(10) *Potamogeton natans* L. [Potamot flottant, Floating Pondweed]CARTE 10. *Potamogeton natans*.

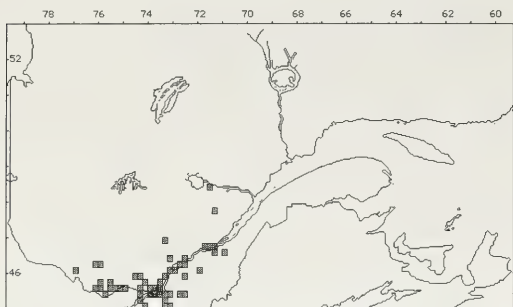
Potamogeton natans est l'une des espèces ubiquistes et abondantes au sud du 49° de latitude. Faisant partie du Groupe III de Hellquist, il s'adapte à tous les milieux. C'est une espèce que l'on rencontrera fréquemment dans les étangs rendus aux derniers stades de comblement, emplies de fine vase organique,

où elle côtoie *Nuphar variegata*. Les rhizomes de *P. natans*, profondément enfouis dans le substrat, possèdent l'aptitude de se maintenir dans ce milieu anaéro-bique. Cette tendance à enfouir profondément son rhizome rend difficile son prélèvement lorsque la plante est installée sur des substrats plus fermes.

La forme elliptique des feuilles flottantes et leurs pétioles plus longs que la profondeur de l'eau permettent à cette espèce de former de grands herbiers aux endroits exposés (Hutchinson 1975) ou dans des plans d'eau dont le niveau varie beaucoup (Sculthorpe 1967). Cependant, elle ne se rencontre pas en présence de courant.

L'espèce, avec ses feuilles submergées phyllodiales ne peut être confondue qu'avec *P. oakesianus*. Et encore, faut-il avoir affaire à des individus immatures. Les caractères indiqués dans la clé permettront de séparer ces deux espèces facilement. *P. natans*, espèce type du genre, a fait l'objet de très nombreux travaux botaniques (Sculthorpe 1967).

Répartition globale: Circumboréale.

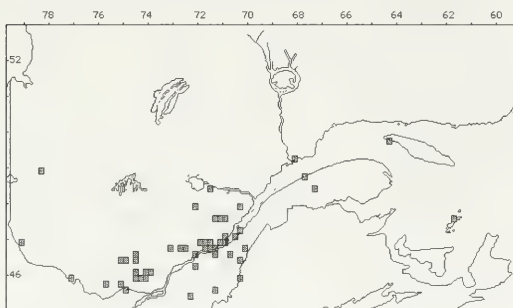
(11) *Potamogeton nodosus* Poir. [Potamot noueux, Longleaf Pondweed]CARTE 11. *Potamogeton nodosus*.

Cette espèce pénètre au Québec par le Sud-

Ouest et est localement abondante dans ce territoire tel que défini plus haut. Bien que d'affinité calcaire (Groupe V de Hellquist) la plante ne se rencontre pas dans l'est du Québec. Une récolte de Saint-Damase, comté de Matapédia, conservée à QFA, doit être rejetée sur la base de l'anatomie de la tige.

Dans les régions du Québec où elle est présente, cette espèce peut être confondue avec *P. illinoensis* et *P. gramineus*. De plus, ces trois espèces hybrident entre elles et avec plusieurs autres. On devra avoir recours à l'étude de l'anatomie de la tige si l'on tient à identifier sûrement des spécimens sans fruits et au port atypique.

Répartition globale: Cosmopolite.

(12) *Potamogeton oakesianus* Robbins [Potamot de Oakes, Oakes' Pondweed]CARTE 12. *Potamogeton oakesianus*.

Potamogeton oakesianus préfère les milieux très acides comme le reflète son appartenance au Groupe I de Hellquist. La répartition de cette espèce au Québec est tout à fait singulière et ne présente de

similitude avec aucune des autres espèces présentes sur le territoire. Si on fait exception des quelques stations périphériques, on constate que *P. oakesianus* est surtout présent au centre de la province et dans la région des Laurentides. La répartition de cette espèce semble donc distincte et contiguë à celle des espèces calciphiles disjointes de notre territoire. En dehors du Québec, l'espèce se concentre en Nouvelle-Angleterre le long de l'Atlantique. Plus au nord, elle atteint des régions maritimes comme en Nouvelle-Écosse et à Terre-Neuve, où elle est toutefois moins abondante. L'explication de la répartition de l'espèce semble donc se trouver dans la recherche de milieux très acides et d'un climat doux.

Potamogeton oakesianus est superficiellement semblable à *P. natans*, avec lequel il pourrait être confondu.

Répartition globale: Nord-est de Amérique du Nord.

(13) *Potamogeton obtusifolius* Mert. & Koch. [Potamot à feuilles obtuses, Bluntleaf Pondweed]CARTE 13. *Potamogeton obtusifolius*.

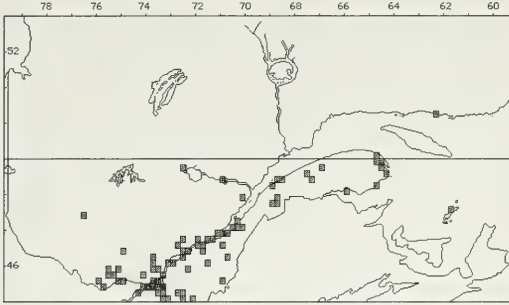
Cette espèce est peu abondante et très dispersée sur le territoire du Québec, présente surtout sur nos frontières sud et ouest. A ces endroits, *P. obtusifolius* est en marge de son aire principale de répartition qui semble être la Nouvelle-Angleterre et l'Ontario (Haynes 1974). Elle se retrouve dans 7 de 29 plans d'eau inventoriés dans le Bas Saint-Laurent, ce qui explique l'apparente abondance de l'espèce pour le Bas Saint-Laurent que montre notre carte. Cela incite à croire qu'en raison de la discrétion de la plante, son abondance réelle sur notre territoire est sous-estimée. Espèce du groupe IV de Hellquist, ses préférences calcaires expliquent son absence au nord du Saint-Laurent.

Habituellement retrouvé en eau relativement profonde de l'infra littoral inférieur, il arrive à l'occasion que l'on rencontre *P. obtusifolius* à faible profondeur. Lorsque rencontrée dans ces conditions, la plante était souvent sous le couvert des feuilles flottantes des macrophytes aquatiques. Hutchinson (1975) indique que l'efficacité de cette espèce à s'adapter à l'eau profonde tient à un faible taux respiratoire.

C'est une espèce qui accomplit tout son cycle de reproduction sous l'eau. Son aspect buissonnant bien particulier, sa teinte rougeâtre et l'extrémité arrondie de ses feuilles en font une espèce facile à reconnaître sur le terrain. Son fruit peut porter une crête ou avoir le dos arrondi. Pour cette raison, l'espèce est incluse deux fois dans notre clé.

Répartition globale: Amérique du Nord. Présent au Nouveau-Québec.

(14) *Potamogeton perfoliatus* L. [Redhead Grass]



CARTE 14. *Potamogeton perfoliatus*.

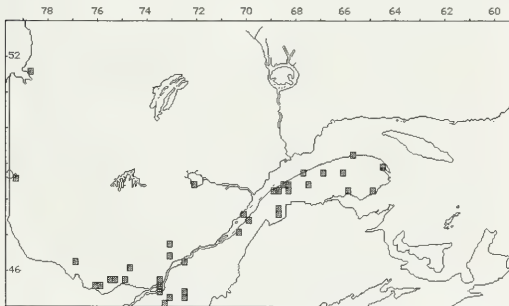
Au Québec, *P. perfoliatus* est ubiquiste au sud du 49° de latitude (groupe III de Hellquist) et est localement abondant. Cette abondance est en effet limitée aux milieux de prédilection de la plante dans certaines régions. On la rencontre fréquemment dans les rivières de la plaine du Saint-Laurent ainsi que dans le

fleuve lui-même. Il est intéressant de remarquer que l'espèce s'éloigne peu du fleuve vers le nord, ce qui marque la limite de son abondance sur le continent, abondance centrée en Nouvelle-Angleterre avec des extensions jusqu'à Terre-Neuve. Par ailleurs, bien que la carte montre plusieurs stations pour le Bas Saint-Laurent elle se rencontre très rarement dans la région. Elle y est certainement très peu abondante.

Potamogeton perfoliatus est une espèce présentant d'importantes variations dans la forme de ses feuilles, parfois sur un même individu. On devra donc être prudent en identifiant l'espèce en l'absence de fruits et confirmer le diagnostic par l'observation des stipules tel qu'indiqué dans la clé. En effet, dans leurs formes extrêmes, cette espèce et *P. richardsonii* peuvent présenter des faciès similaires. Ces deux espèces sont aussi connues pour hybrider (Dobson et Catling 1983).

Répartition globale: Cosmopolite. Synonymie: *P. bupleuroides* Fernald, *Potamogeton perfoliatus* L. var. *bupleuroides* (Fern.) Farwell

(15) *Potamogeton praelongus* Wulfen [Potamot à longs pédoncules, Whitestem Pondweed]



CARTE 15. *Potamogeton praelongus*.

Potamogeton praelongus montre une répartition disjointe dans le Québec méridional. Calciphile du groupe IV de Hellquist, la plante est localement

abondante. Autre exemple d'une plante discrète que l'on connaît mal, elle a été retrouvée dans 66% des plans d'eau inventoriés dans le comté de Rimouski. Ceci semble contredire Marie-Victorin (1997) qui la disait rare au Québec.

Potamogeton praelongus est une espèce sans feuille flottante de l'infra littoral inférieur. C'est l'une de nos très grandes espèces, pouvant atteindre plus de 2 m. À première vue, elle pourrait être confondue avec *P. amplifolius* qui cependant développe des feuilles flottantes lorsqu'il atteint la surface. L'extrémité cucullée des feuilles de *P. praelongus* dissipera rapidement toute confusion. À l'état frais on sent facilement cette forme avec l'extrémité du doigt, alors que sur les spécimens pressés et séchés, l'extrémité de la feuille se fend longitudinalement. Ses feuilles ont aussi plutôt tendance à être tirebouchonnées alors que celles de *P. amplifolius* sont

arquées. *P. praelongus* présente aussi de fortes stipules dont la couleur blanchâtre est distinctive. Comme beaucoup d'espèces sans feuille flottante, l'extrémité du pédoncule émerge pour permettre la

floraison puis se retire sous l'eau pour mûrir ses fruits.
Répartition globale: Circumboréale. Présent au Nouveau-Québec.

(16) *Potamogeton pusillus* L. [Potamot nain, Slender Pondweed]

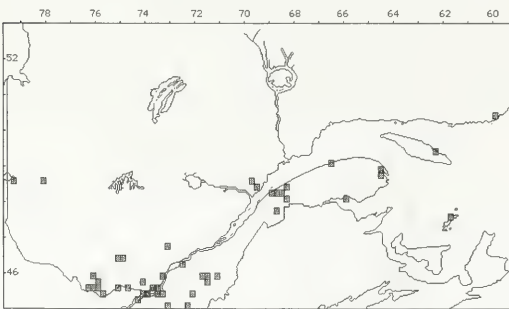
Cette espèce et ses sous-espèces furent longtemps mal comprises, en grande partie parce que les étudiants du genre ont utilisé des caractères végétatifs qui variaient selon la saison et le milieu de croissance (Haynes 1974). Lorsqu'il a monographié la sous-section Pusilli, Haynes (1974) a proposé une mise en ordre de l'espèce qui est retenue ici. Seuls les spécimens d'herbiers identifiés à la variété (maintenant désignée sous-espèce) ont été conservés pour les cartes. Ceci a éliminé une partie importante des récoltes, en conséquence de quoi l'espèce est beaucoup plus abondante que ne le laisse supposer le nombre de stations présentes sur les cartes. De

même, cette abondance est sous-estimée dans la figure n°1.
Les trois taxons infraspécifiques dont il sera ici question étaient jusqu'à tout récemment décrit comme des variétés. Haynes et Hellquist (1996) signalent qu'il est maintenant plus approprié d'utiliser le rang de sous-espèce pour décrire ce niveau de division de l'espèce. La clé suivante permet de distinguer ces sous-espèces. Comme Haynes, on ne saurait trop recommander de ne tenter l'identification que sur des spécimens fertiles dont les fruits sont bien mûrs.

- Feuilles munies de 1-5 nervures, larges de 0,2 à 2,5 mm, à l'extrémité aiguë à obtuse.
- Fruits plus larges au-dessus du milieu, à côtés concaves et bec central; pédoncules filiformes à cylindriques, habituellement de 1 à 3 par individu; inflorescence habituellement composée de 2-4 verticilles distincts; feuilles munies de 1-2 bandes lacunaires de part et d'autre de la nervure centrale, à l'extrémité aiguë, rarement apiculée; stipules habituellement connées. a) sous-esp. *pusillus*
- Fruits plus larges au milieu ou sous le milieu à côtés convexes et bec incliné vers l'avant; pédoncules cylindriques, habituellement plus de 3 par individu; inflorescence habituellement composée de 1-2 verticilles adjacents; feuilles munies de 1-5 bandes lacunaires de part et d'autre de la nervure centrale, à l'extrémité aiguë à obtuse; stipules habituellement convolutées. b) sous-esp. *tenuissimus*
- Feuilles uninervées, larges de 0,2 à 0,7 mm, subulées. c) sous-esp. *gemmiparus*

Répartition globale: L'espèce est cosmopolite (Hutchinson 1975).

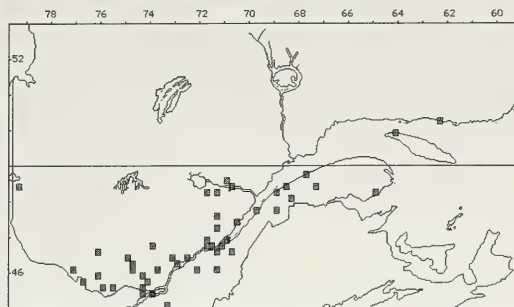
(16a) *Potamogeton pusillus* sous-esp. *pusillus*



CARTE 16. *Potamogeton pusillus* sous-espèce *pusillus*.

Cette sous-espèce d'affinité calcaire (Groupe V de Hellquist) montre une répartition disjunkte typique des plantes de ce groupe. Elle est localement abondante.
La plantule produite par le fruit de cette espèce ressemble beaucoup à l'hibernacle de l'espèce et persiste à la base de la plante durant la saison de croissance (Muenscher 1936). Ces deux structures peuvent alors être confondues. L'origine sexuée ou végétative de tels individus est alors douteuse.
Synonymie: *P. lateralis* Morong (en partie).

(16b) *Potamogeton pusillus* L. sous-esp. *tenuissimus* (F. K. Mertens & W. D. Koch) R. R. Haynes & C. B. Hellquist

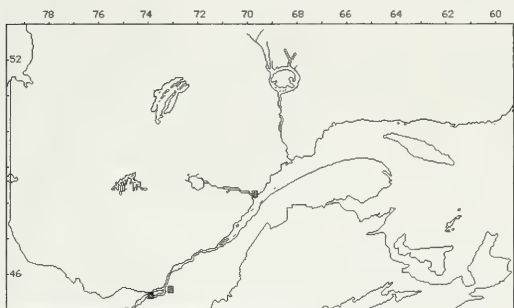


CARTE 17. *Potamogeton pusillus* sous-espèce *tenuissimus*.

Cette sous-espèce montre une répartition ubiquiste au sud du 49° parallèle. Cette répartition est typique des espèces du Groupe III de Hellquist. Ce serait, avec *P. praelongus*, l'une des plantes aquatiques les plus tolérantes à l'ombre (Hutchinson 1975). Ceci lui permet de coloniser les fonds de fine vase organique que l'on retrouve à grandes profondeurs.

Présente au Nouveau-Québec. Synonyme: *P. berchtoldii* Fieb.

(16c) *Potamogeton pusillus* L. sous-esp. *gemmiparus* (Robbins) R. R. Haynes & C. B. Hellquist

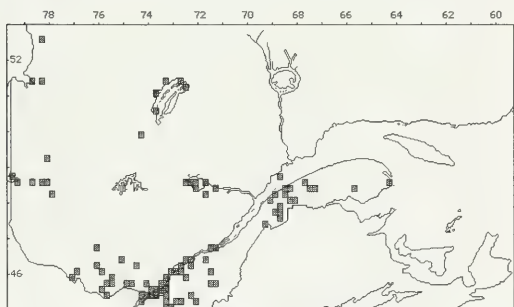


CARTE 18. *Potamogeton pusillus* sous-espèce *gemmiparus*.

Cette sous-espèce est sans contredit le plus rare des Potamogetons du Québec. C'est un taxon acidiphile du Groupe I de Hellquist. Sa grande rareté ne permet pas de vérifier s'il montre cette préférence sur notre territoire. C'est une espèce de la liste des plantes rares de Bouchard et al. (1983) et de celle de Lavoie (1992).

Synonyme: *P. gemmiparus* (Robbins) Morong.

(17) *Potamogeton richardsonii* (Bennet) Rydberg [Potamot de Richardson]



CARTE 19. *Potamogeton richardsonii*.

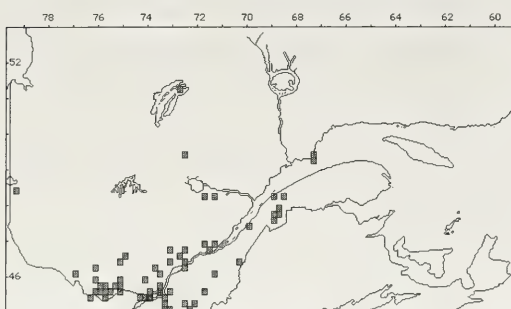
Potamogeton richardsonii est abondant au Québec (graphique n°1) et montre une légère préférence pour les milieux calcaires (Groupe IV de Hellquist, Hogdon et al. 1952). Ceci se reflète sur la carte par la concentration de l'espèce dans certaines régions

du Québec. Cette répartition place *P. richardsonii* en position intermédiaire entre les espèces ubiquistes et les espèces à répartition disjointe.

C'est une espèce fréquente en eaux courantes. Ses feuilles sont renforcées de fortes nervures permettant à la plante de résister au courant parfois fort des rivières. On rencontre souvent des individus maintenus couchés par le courant et atteignant une longueur dépassant de plusieurs fois la profondeur d'eau disponible. Dans de tels milieux, la plante s'enracine dans les graviers parfois grossiers du fond de la rivière. Elle pourrait être confondue avec *P. praelongus*. L'extrémité cucullée des feuilles de ce dernier lèvera immédiatement tout doute. Voir aussi le commentaire sous *P. perfoliatus*.

La plante possède le mode de pollinisation hydro-anémophile décrit sous *S. pectinata*.

Répartition globale: Amérique du Nord. Présent au Nouveau-Québec. Synonyme: *P. perfoliatus* L. var. *richardsonii* (Bennett) Hult.

(18) *Potamogeton robbinsii* Oakes [Potamot de Robbins, Fern Pondweed]CARTE 20. *Potamogeton robbinsii*.

Endémique de l'Amérique du Nord, cette magnifique espèce est symptomatique de la méconnaissance de la famille *Potamogetonaceae* au Québec. La littérature à son sujet est très dispersée. Lorsque furent rencontrés les immenses herbiers que forme l'espèce dans certains lacs du comté de Rimouski, il a fallu se référer à une Flore de l'Alaska (Hulten 1968) pour consulter une carte de répartition. Scoggan (1950) ne mentionne pas du tout l'espèce dans sa Flore du Bic, et Lavoie (1984) la cite en 3 endroits du comté voisin de Témiscouata. Pourtant, elle est présente dans 8 des 29 plans d'eau du Bas Saint-Laurent inventoriés pour cette étude. Dans certains cas l'espèce est dominante. On peut rencontrer l'espèce dans toutes les parties d'un lac, mais elle est surtout présente dans l'infra-littoral moyen et inférieur. Elle abonde dans les zones profondes.

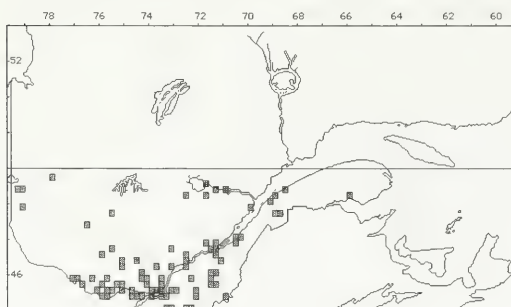
Faisant partie du groupe II de Hellquist, mais à la limite du groupe III, l'espèce peut être décrite comme ubiquiste mais possédant une légère préférence acidiphile. Malgré cela, elle est très abon-

dante dans certains lacs du Bas Saint-Laurent qui, d'autre part, renferment des espèces ayant des préférences très nettement calcaires. La répartition de *P. robbinsii* au Québec est particulière et reflète les préférences mal tranchées de l'espèce. C'est le seul cas où l'on peut interpréter la répartition en ayant recours aux nombres de degrés-jours de croissance. En effet on constate une similitude entre la répartition de la plante et les régions ayant plus de 1440 degrés-jours de croissance (Thibault 1985).

Potamogeton robbinsii est l'une des espèces facile à reconnaître. Ses feuilles munies sur le pourtour d'une bande d'aspect cartilagineux souvent dentée, ses ligules à l'extrémité divisée en deux pointes et son port distique peu ramifié la font reconnaître immédiatement. Ses feuilles sont auriculées à la base. La floraison est aérienne et il arrive que l'on rencontre des colonies qui fleurissent abondamment. Ces groupes de plantes doivent être observés attentivement car les fruits de l'espèce sont très rares. En effet on ne retrouve à peine que 2 ou 3 mentions de l'observation de ces fruits pour tout l'Amérique du Nord, toutes aux États-Unis (Fernald 1932, Aalto 1974, Hellquist communication personnelle). La récolte par l'auteur de spécimens fructifiés dans le comté de Rimouski à l'été 1998 mérite donc d'être mentionnée ici. On croit que l'espèce est d'origine hybride très ancienne.

Il se pourrait que la forme *cultellatus* Fassett (Fassett 1933), dont les feuilles sont dépourvues de dents marginales, ne soit qu'une variation liée au milieu. Les collections de spécimens montrent une gamme importante de la taille des dents, les individus à dents minuscules ou absentes étant souvent récoltés à l'ombre des macrophytes flottantes.

Répartition globale: Amérique du Nord.

(19) *Potamogeton spirillus* Tuckerm. [Potamot spirillé, Northern Snailseed Pondweed]CARTE 21. *Potamogeton spirillus*.

Potamogeton spirillus est une espèce ubiquiste au sud du 49° parallèle de latitude. Elle est plutôt acidiphile et fait partie du groupe II de Hellquist. Ceci explique que son abondance diminue lorsque l'on progresse vers l'est de la province où elle se fait peu abondante. Cette présence erratique dans l'est rappelle la répartition de *P. perfoliatus*.

Potamogeton spirillus ne peut être confondu qu'avec *P. vaseyi*. L'observation des stipules lèvera immédiatement le doute. *P. spirillus* a de plus tendance à présenter des feuilles submergées arquées. En l'absence de feuilles flottantes, l'espèce pourrait être déroutante au premier abord. L'observation des

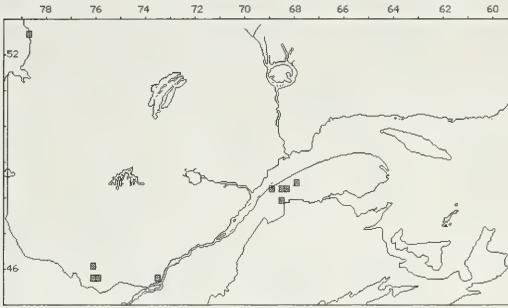
fruits et des stipules rendra l'identification possible. C'est une des rares espèces qui présentent la particularité de développer à la fois des inflorescences aériennes et submergées.

Potamogeton bicupulatus Fern, une espèce présente en Ontario et dans les états américains bordant le Québec, ressemble à *P. spirillus*. Elle pourrait éventuellement être récoltée dans les régions de la province qui sont voisines de son territoire connu. Bien que les deux espèces soient

superficiellement semblables, *P. bicupulatus* présente une ligule qui est plus longue que la partie adnée de la stipule, alors que chez *P. spirillus* la ligule est plus courte. De plus, le fruit de *P. bicupulatus* présente deux crêtes latérales en plus de la crête dorsale. Ces crêtes peuvent porter des tubercules plus ou moins prononcés (Reznicek et Bobette 1976)

Répartition globale: Nord-est de l'Amérique du Nord.

(20) *Potamogeton strictifolius* Ar.Benn. [Potamot à feuilles raides, Straight-leaved Pondweed]



CARTE 22. *Potamogeton strictifolius*.

Cette espèce fait partie du Groupe V de Hellquist. C'est une espèce d'affinité calcaire, montrant une répartition disjointe. Elle est très dispersée et constitue une espèce très peu abondante sur notre territoire. Il n'apparaît pas clairement si la plante est réellement plus abondante au Bas Saint-Laurent comme semble le montrer la carte ou bien s'il s'agit là d'un artéfact dû à l'effort d'herborisation de cette région dans le cadre de la présente étude. La discrétion de l'espèce rend plausible qu'elle soit plus abondante qu'il est illustré ici. Cette méconnaissance de l'espèce et son intolérance à la pollution font de *P. strictifolius* un candidat intéressant à des travaux floristiques plus élaborés.

Il existe une ressemblance superficielle entre cette espèce et les autres taxons à feuilles étroites et sans feuilles flottantes, particulièrement *P. pusillus* et *P. foliosus*. Sous la loupe, les stipules fibreuses de *P. strictifolius* ne laissent pas place au doute. Sur le terrain, on peut soupçonner avoir affaire à cette espèce parce que *P. strictifolius* a tendance à présenter des individus isolés, dressés verticalement dans l'eau calme, et dont les feuilles sont disposées de façon

distique. Les deux autres espèces ont plutôt tendance à former des masses emmêlées d'individus, et bien que leurs feuilles soient disposées sur deux rangs, on ne peut les qualifier de distiques. Évidemment, il est nécessaire de recourir aux caractères techniques pour identifier réellement la plante.

Potamogeton strictifolius et *P. zosteriformis* forment un hybride fertile et qui est décrit comme une nouvelle espèce sous le nom *Potamogeton x haynesii* Hellquist & Crow. Ce taxon était autrefois connue sous le nom *P. longiligulatus*. (Hellquist et Crow 1986). Bien que cette espèce ne soit pas encore signalée sur notre territoire, elle est présente au Vermont près de la frontière. On la retrouve aussi en Ontario. Elle pourrait se retrouver au Québec dans les régions où les espèces parentes sont présentes. Cette espèce ressemble beaucoup à *P. strictifolius* duquel elle diffère par le nombre élevé de nervures des feuilles (7-21) (Hellquist et Hilton 1983).

Une autre espèce, inconnue au Québec, ressemble assez à *P. strictifolius*. Il s'agit de *P. hillii*, présent dans les états de New York, du Vermont et en Ontario. Elle pourrait donc être un jour découverte dans les régions du Québec limitrophes de ces territoires. *P. hillii* se distinguera alors par des fruits présentant une crête, long de 2,3 à 4 mm. ainsi qu'un épi capité portant 1 ou 2 verticilles rapprochés. Chez *P. strictifolius* le fruit atteint 2,1 mm. et l'épi est cylindrique, portant 3 ou 4 verticilles espacés (Haynes 1974). Ce dernier présente aussi des glandes plus importantes et une marge distincte autour de la feuille (Hellquist 1984).

Potamogeton strictifolius est l'une des espèces qui complètent leur cycle reproducteur en restant submergées. Pollinisation aquatique, apomixie, ou fécondation cleistogame?

Répartition globale: Nord-est de l'Amérique du Nord. Synonymie: *P. strictifolius* Ar. Benn. var. *rutiloides* Fern.

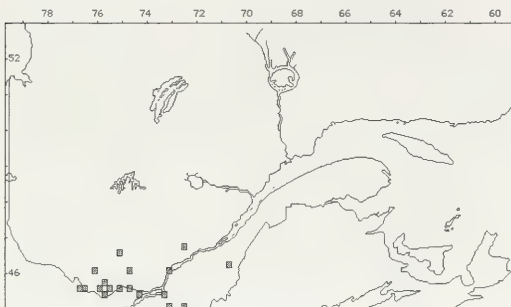
(21) *Potamogeton subsibiricus* Hagstr.

Cette espèce se retrouve uniquement dans les régions septentrionales du Québec. Blondeau et Cayouette (1987) qualifient sa répartition de «bas-arctique nord-américain et est-asiatique». Leur carte n°11 montre les 5 stations connues du Nouveau-Québec, autour de la Baie d'Hudson et de la Baie d'Ungava. Il n'a pas été trouvé à ajouter à cette

répartition. L'espèce est potentiellement rare selon Bouchard et al. (1983).

Les nombreuses nervures des étroites feuilles de cette espèce sont très caractéristiques. Toutes nouvelles récoltes de l'espèce seraient dignes de mention.

Synonyme: *P. porsildiorum* Fern.

(22) *Potamogeton vaseyi* Robbins [Potamot de Vasey, Vasey's Pondweed]

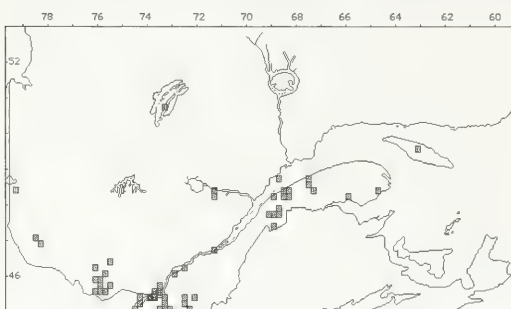
CARTE 23. *Potamogeton vaseyi*.

Québec. En effet, elle est présente dans des régions où se retrouvent habituellement des espèces d'affinité calcaire. La plante, ici à la limite nord de sa répartition sur le continent, adopte peut-être un comportement différent de celui qui est le sien dans son aire principale. C'est une espèce rare au Québec selon Bouchard et al. (1983) et Lavoie (1992). Ceci devrait peut-être être réévalué à la lumière de nos cartes. Plusieurs autres espèces montrent une répartition plus clairsemée sans avoir le statut de «rare». Il apparaît que la plante atteint la limite septentrionale de sa répartition nord-américaine dans le comté de Champlain, par 46°48'N. et 072°31'O.

Potamogeton vaseyi est plus susceptible d'être confondu avec *P. spirillus* qu'avec nos autres espèces à feuilles linéaires. Voir les remarques sous cette dernière espèce.

Répartition globale: Nord-est de l'Amérique du Nord. Synonymie: *P. lateralis* Morong (en partie).

% Comme trois autres espèces, *P. vaseyi* pénètre au Québec par le sud-ouest de la province où elle se cantonne. C'est, d'après Hellquist (1980) une espèce d'affinité acide (Groupe II). Ceci n'apparaît pas clairement dans la répartition de la plante au

(23) *Potamogeton zosteriformis* Fern. [Potamot zostériforme, Flatstem Pondweed]

CARTE 24. *Potamogeton zosteriformis*.

une espèce d'affinité calcaire montrant une répartition disjointe tout à fait typique. Elle est localement abondante.

Potamogeton zosteriformis, malgré sa taille, peut être très discret. Sans feuille flottante, souvent présent dans l'infra-littoral inférieur, il ne forme pas de colonie mais croît individuellement dans les espaces laissés libres par la végétation. Il a été récolté dans 69% des plans d'eau du comté de Rimouski. Sa tige très aplatie et ses feuilles linéaires abondamment nervurées en font une espèce facilement identifiable. Cependant comme le fait justement remarquer Marie-Victorin (1997), un examen superficiel pourrait faire confondre cette espèce avec *Heteranthera dubia*, dans les régions où les 2 espèces cohabitent.

Répartition globale: Amérique du Nord.

Cette espèce du Groupe IV de Hellquist (1980) est

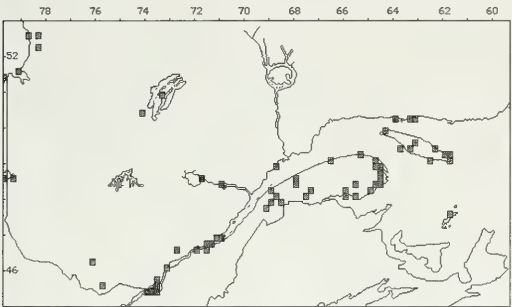
(24) *Stuckenia filiformis* (Pers.) Börner [Potamot filiforme, Threadleaf Pondweed]

Des travaux récents (Les et Haynes 1996) ont proposé d'élever le sous-genre *Coleogeton* (dont faisait partie la présente espèce) au rang de genre. Il a alors été signalé par Holub (1997) que le nom de genre *Stuckenia*, proposé en 1912, avait priorité. Au

Québec, ce changement affecte la présente espèce ainsi que *Stuckenia pectinata* (*P. pectinatus*).
On retrouve au Québec deux sous-espèces, que l'on peut distinguer ainsi:

- Plante courte, tige habituellement longue de 1-3 dm. Stipules situées à la partie inférieure de la plante enserrant étroitement la tige a) sous-espèce *alpina*
- Tige habituellement longue de 3-5(10) dm. Stipules situées à la partie inférieure de la plante lâches et gonflées b) sous-espèce *occidentalis*

(24a) *Stuckenia filiformis* (Pers.) Börner sous-espèce *alpina* (Blytt) Haynes, Les & Kral



CARTE 25. *Stuckenia filiformis* sous-espèce *alpina*.

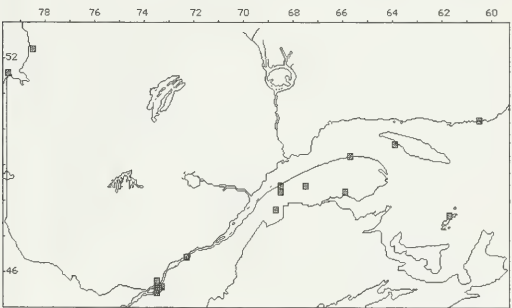
Cette sous-espèce est un taxon d'affinité calcaire (Groupe V de Hellquist), abondant et montrant une répartition disjointe au Québec. De plus, cette répartition a un aspect très particulier. A l'est, la plante est

un élément commun, que l'on rencontre partout dans les régions calcaires. À l'ouest cependant, et contrairement à la plupart des autres espèces disjointes, la plante se concentre presque exclusivement dans le Saint-Laurent. Une autre espèce, *S. pectinata* présente aussi un tel patron de répartition sur le territoire. Comme cette dernière espèce, *S. filiformis* sous-espèce *alpina* possède peut-être une grande capacité de s'adapter à la vie en eaux polluées.

Dans le Bas Saint-Laurent, on la rencontre fréquemment en eau calme sur un substrat de fine vase organique. La plante y fait courir de longs rhizomes qu'il est facile de récolter. La pollinisation est hydrophile, cette plante effectuant tout son cycle de reproduction sous l'eau.

Répartition globale: Circumboréale, Afrique. Présent au Nouveau-Québec. Synonyme: *Potamogeton filiformis* Pers. var. *alpinus* (Blytt) A. & G., *P. filiformis* var. *borealis* (Raf.) St.John.

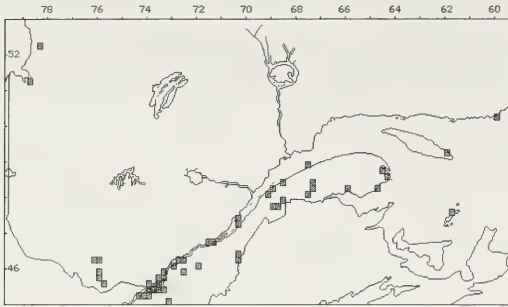
(24b) *Stuckenia filiformis* (Pers.) Börner sous-espèce *occidentalis* (Robbins) Haynes, Les & Kral



CARTE 26. *Stuckenia filiformis* sous-espèce *occidentalis*.

Cette seconde sous-espèce est beaucoup plus rare sur notre territoire. Les quelques stations qu'il a été possible de pointer sur la carte semblent témoigner d'une répartition similaire à la variété précédente. Il s'agit donc d'une espèce d'affinité calcaire, disjointe et occasionnelle au Québec.

Répartition globale: Circumboréale, Afrique. Synonyme: *Potamogeton filiformis* Pers. var. *occidentalis* (Robbins) Morong., *Potamogeton filiformis* var. *macounii* Morong,

25) *Stuckenia pectinata* (L.) Börner [Potamot pectiné, Sago Pondweed]CARTE 27. *Stuckenia pectinata*.

Localement abondant au Québec, *S. pectinata* présente une répartition disjointe au sud du Saint-Laurent. Il abonde dans le fleuve lui-même en amont de Québec. Deux caractéristiques très marquées de l'espèce expliquent cette répartition: sa préférence marquée pour les eaux très dures (Groupe VI de Hellquist) et sa capacité à tolérer une très haute teneur en électrolytes dans son milieu. Cette dernière caractéristique explique la présence de l'espèce dans des milieux naturels comme les estuaires saumâtres et les lacs volcaniques contenant de fortes quantités de chlore, sulfate, phosphore et sodium (Sculthorpe 1967). Cette capacité permet aussi à la plante de s'adapter et de proliférer dans les eaux très polluées des régions industrielles. Ceci fait de *S. pectinata* une espèce au moins aussi étudiée que *P. natans*. Au Québec, *S. filiformis* sous-espèce alpine présente une répartition simi-

laire. On retrouve aussi ces deux espèces en eaux saumâtres (Ogden 1974; Marie-Victorin et Rolland-Germain 1969).

Le mode de pollinisation de cette espèce est intermédiaire entre la pollinisation aérienne et aquatique et peut être qualifié d'hydro-anémophile (Sculthorpe 1967). Au moment de l'anthèse, l'inflorescence est élevée hors de l'eau mais affleure la surface. Le pollen est transmis d'un individu à l'autre en flottant sur la surface, comme chez *Elodea*. L'épi flotte à la surface de l'eau pour la maturation du fruit. Cette fructification est abondante.

Le port très élané de la plante et la grande flexibilité de toutes ses parties en font une espèce caractéristique des rivières à courant moyen à faible. Lorsque récolté dans un lac, *S. pectinata* provient souvent d'un secteur où l'eau est en mouvement, comme dans un étranglement ou bien dans la région de l'émissaire.

Cette espèce se reproduit végétativement au moyen de boutures tubéreuses produites par le rhizome (Marie-Victorin 1997, Yeo 1965). Selon une étude fréquemment citée de Yeo (1965), un seul fruit peut produire en une saison 36 000 de ces boutures ou 63 300 nouveaux fruits. On peut observer chez cette espèce la tendance que montrent plusieurs Potamogetons de se multiplier végétativement de façon abondante tard dans la saison, après avoir muris leurs fruits.

Toutes ces caractéristiques font de *S. pectinata* une mauvaise herbe nuisible en bien des endroits.

Répartition globale: Cosmopolite. Synonymie: *Potamogeton pectinatus* L.

Conclusion

Contrairement à une réputation voulant que les espèces de Potamogetonaceae forment un groupe de plantes difficiles à identifier, dans la plupart des cas, il est possible de distinguer aisément les différentes espèces présentes au Québec si des critères pertinents et stables sont observés sur des spécimens complets.

La répartition des différentes espèces sur notre territoire est liée principalement à l'affinité de l'espèce pour les carbonates. L'impact du nombre de degrés-jours de croissance est atténué et plus difficile à cerner. On constate que les espèces ayant des affinités calcaires similaires se répartissent aussi de façon similaire. Les espèces les plus tolérantes aux variations de la teneur en HCO_3^- sont aussi les espèces les plus ubiquistes au Québec. Un grand nombre d'espèces sont calciphiles et présentent une répartition disjointe entre l'est et l'ouest de la province. De par la nature azonale des milieux aquatiques, il existe de nombreuses mentions de la

présence d'une espèce hors de son aire principale de dispersion. De telles mentions doivent être expliquées par les conditions locales.

Les espèces les plus répandues et abondantes au Québec sont: *P. gramineus* et *P. epihydrus*. Les espèces les moins abondantes et le moins souvent rencontrées sont *P. pusillus* var. *gemmiparus*, *P. subsibiricus* et *P. strictifolius*. L'abondance réelle au Québec de certaines espèces est encore mal connue. Un effort d'herborisation dans le comté de Rimouski a révélé que certaines espèces sont beaucoup plus abondantes que la littérature ou les grandes collections d'herbiers ne laissent croire. Un cas d'espèce est *P. strictifolius*. De même, *P. praelongus* et *P. zosteriformis* semblent très sous-représentés dans les herbiers consultés. Ceci s'explique par la méconnaissance des espèces, leur discrétion et la difficulté d'accès à leur milieu. Une espèce, *P. vaseyi*, atteint au Québec sa limite septentrionale de répartition sur le continent. Encore inconnues au Québec, mais présentes dans les régions lim-

itrophes, les espèces suivantes pourraient un jour être découvertes sur notre territoire: *P. × haynessii*, *P. hillii* et *P. bicupulatus*.

Les Potamogetonacées, de par leur susceptibilité distincte à tolérer les eaux polluées peuvent servir d'indicateur de l'état et de l'évolution de la qualité d'un plan d'eau. Leur importance est énorme pour la faune aquatique ou ailée ainsi que pour certains mammifères. Pourtant, leur répartition et leur abondance sont encore imparfaitement connues au Québec. Pour documenter plus précisément nos espèces, des efforts d'herborisation sont nécessaires dans les milieux aquatiques de la province, particulièrement chez les petits plans d'eau calme qu'affectionne la famille.

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Age and Size of Wood Frogs, *Rana sylvatica*, from Kuujuarapik, Northern Quebec

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Length and age of 53 Wood Frogs, *Rana sylvatica*, from Kuujuarapik in northern Quebec (55°17'N) were compared with similar data from populations in more southern latitudes. Age was estimated by skeletochronology. Mean snout-urostyle length and age were 47.1 mm and 6.1 years in adult males (n = 41) and 50.9 mm and 7.7 years in adult females (n = 8). There was no significant correlation between age and size. The youngest mature males and females were 4 and 6 years old respectively. Mean physiological longevity (mean age in years multiplied by annual number of frost-free days) was 397 days for males and 504 days for females. Comparisons with other populations suggest that sexual dimorphism in size, age, and longevity are species characteristics. Size and age increase with latitude in lowland populations. Physiological longevity is positively related to body size in males from lowland and upland populations. The data do not support the hypothesis that maturity at an early age in males curtails their potential life span. They are consistent with the prediction of longer life span at lower ambient temperatures. In female Wood Frogs, physiological longevity does not follow geographical variation in adult body size.

Key Words: Wood Frog, *Rana sylvatica*, age, growth, longevity, skeletochronology, Kuujuarapik, Quebec.

The geographic range of the Wood Frog (*Rana sylvatica*) is one of the most extensive among North American ranids. It covers the eastern United States in the favorable forested habitats of the Appalachian and Ozark Mountains, the states of New England, almost all the eastern Canadian provinces including Labrador, the northern two-thirds of Saskatchewan, Alberta and British Columbia, and part of the Northwest Territories, Yukon and Alaska (Cook 1984; Conant and Collins 1991) (Figure 1). This cold-adapted species even occurs within the Arctic Circle (up to 69°N); its northern distribution generally follows the northern tree limit.

Such wide distributions in anurans give opportunities for investigation of geographic variations in phenotypic traits such as pigmentation pattern, body proportions, or body size (Ruibal 1957; Martof and Humphries 1959; Pace 1974; Schueler 1982). A general tendency of the Wood Frog for decreasing adult body size with increasing latitudes was established by Martof and Humphries (1959) who, accordingly, concluded that the average body size was a direct consequence of the climate or, more accurately, of the duration and quality of the activity season. Some reverse tendencies in specific regions of north America (Michigan Wood Frogs with smaller than predicted body size, for instance) were tentatively related to historic recolonizations after the Wisconsin glaciation (Martof and Humphries 1959).

Geographic variations in body size of poikilotherms have been repetitively studied in causal relation with ambient temperature (Ray 1960; Atkinson 1994). However, latitudinal and altitudinal trends in anuran body size differ among and within species, perhaps because of demographic strategies (Berven 1982; Hemelaar 1988; Leclair and Laurin 1996). Berven (1982) has suggested for instance, that female Wood Frogs from highland Virginia reach large size due to selection for the production of large eggs in a cold environment. Leclair and Laurin (1996) had related the larger size of northern *R. septentrionalis* to delay in maturity, higher growth rate, and greater mean ages, in comparison with more southern populations.

Most of the demographic data for the adult Wood Frogs come from the extensive studies of Berven (1981, 1982, 1988, 1990), who made use of capture-recapture methods, and from the works of Bastien and Leclair (1992) and Sagor et al. (1998), who estimated age by means of skeletochronology. Bastien and Leclair (1992), using pooled demographic data from Berven (1982), computed mean body size, mean age, and physiological longevity (mean age in years \times number of frost-free days per year) for resident Wood Frogs from lowland Maryland and upland Virginia, and compared the data with those from a Wood Frog population at Trois-Rivières (Quebec). These studies revealed that, in males as in

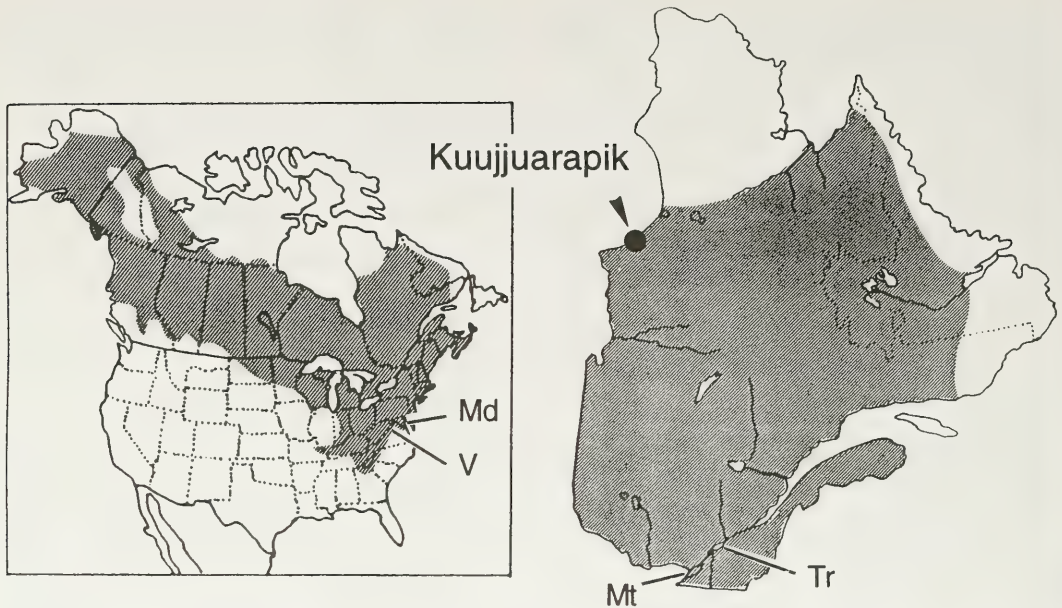


FIGURE 1. General distribution of the wood frog, *Rana sylvatica*, in North America (Md = Maryland V = Vermont) and localization of the study area (Kuujjuarapik) in Quebec Province (Mt = Montreal, Tr = Trois Rivières).

females, both size and age increased from lowland Maryland to Trois-Rivières to upland Virginia. It was also concluded from these studies that physiological longevity in females was stable in the various populations, although body size, mean age, and age at maturity, varied. In males, however, because physiological longevity decreased when mean age decreased, Bastien and Leclair (1992) suggested that early maturity in male Wood Frogs might curtail the length of their potential life span. Data on size and age of Wood Frogs from Ste-Anne-de-Bellevue on Montreal Island (145 km south of Trois-Rivières) furnished by Sagor et al. (1998) fit perfectly with these geographic trends; physiological longevity was not computed, however.

Many of the body size tendencies of Wood Frogs established by Martof and Humphries (1959) rest on a limited number of museum specimens (14 for all of Quebec; only one specimen from Great Whale River). Moreover, age has infrequently been determined in Wood Frog demographic studies, although body size of breeding adults is a widely measured variable. It is therefore worthwhile to study additional populations of *R. sylvatica* in order to better relate geographic variations in age/size relationships to environmental conditions.

The present work addresses whether a population of Wood Frogs (a sample of 41 adult males and 8 adult females) from Kuujjuarapik, northern Quebec, supports or contradicts the geographic trends in size, age, and physiological longevity found for Wood

Frogs from the study of a few populations where age could be determined (Berven 1982; Bastien and Leclair 1992; Sagor et al. 1998). Owing to cold ambient temperatures and the very short growing season in Kuujjuarapik, we expected older and larger Wood Frogs here than anywhere south of this locality. We also asked: Does physiological longevity remain stable among female populations of Wood Frogs? and Does this parameter continue to vary with age in males?

Material and Methods

Kuujjuarapik (Poste-de-la Baleine) is situated on the east shore of Hudson Bay at the mouth of the Great Whale River (55°17'N, 77°45'W) (Figure 1). The study site, on the northeastern limit of the village, is 1.3 km from the Hudson Bay coast and encompasses one main pond (50 m in diameter, 1 m depth) that overflowed into four secondary ponds (10 m in diameter, less than 10 cm depth). These ponds were fed by snow melt. There are an average of 65 frost-free days per year in the region (Wilson 1971). Breeding Wood Frogs were caught by hand or dipnet in ponds, during the day or at night, between 8 June and 8 July 1991. Air and water temperatures on 11 June at 1500h were 8 and 10°C respectively. The frogs were sexed (males with strong forearms and nuptial thumb pads), measured to nearest mm (SUL: snout-urostyle length), their longest (fourth) hind digit amputated at the level of articulation between the first and second proximal

phalanges (for age estimation by skeletochronology), and released alive at the site of capture.

The age of frogs was estimated by the spatial distribution of the lines of arrested growth (LAG) in cross-sectioned phalanges, taking into account endosteal resorption that can destroy the most inner LAGs (Leclair 1990; Bastien and Leclair 1992). The phalanges were hand-cleaned, decalcified in 3% nitric acid, and cut into 16 μm thick sections with a freezing microtome. Sections were stained with Ehrlich hematoxylin and mounted on glass slides in glycerin. The age of each animal was independently estimated by the first three authors. The estimates of ages never diverged more than one year between the three interpretations. Divergences were mostly due to difficulties in separating the more closely packed peripheral LAGs in the oldest animals. Partial resorption of the first LAG occurred in 27% and complete resorption in 35% of the animals. No known-aged individuals were available. The analysis rests on the premise that LAGs in this population of *R. sylvatica* are annual formations as has been experimentally demonstrated in other cold temperate ranid frogs (Smirina 1972; Francillon and Castanet 1985).

The sample size of females was too low to attempt statistical intersex comparisons. However, we used linear regressions to test the relationships between age and size in both sexes. Statistics were generated with the StatView Students program.

Results and Discussion

Adult female body size (SUL) ranged from 47 to 54 mm (mean: 50.9 mm) whereas adult male body

size ranged from 41 to 50 mm (mean: 47.1 mm) (Figure 2). A sexual size dimorphism in favour of females was also encountered in other populations of Wood Frog (Cook 1967; Berven 1982; Gilhen 1984; Davis and Folkerts 1986; Bastien and Leclair 1992; Sagor et al. 1998) and in the museum specimens examined by Martof and Humphries (1959).

The mean age of adult female Wood Frogs from Kuujjuarapik was 7.7 years (range: 6–10 years) whereas that of adult males was 6.1 years (range: 4–8 years; Figure 3). Female Wood Frogs from Maryland-Virginia (Berven 1982) and from more southern Quebec (Bastien and Leclair 1992; Sagor et al. 1998) also averaged older than males. However, there was no correlation between body size and age in the study population ($r = 0.058$ in males, $r = 0.59$ in females; $p > 0.05$ in both cases). The correlation between age and size is generally low in amphibians (Halliday and Verrell 1988) although it was significant in both sexes in the Wood Frog population of Trois-Rivières (Bastien and Leclair 1992). Higher longevity after the attainment of adult body size (Table 1) and strong year-to-year variations in growth performance of Wood Frogs in northern conditions may explain the loss of correlation between size and age at Kuujjuarapik. Similarly, Hemelaar (1988) found that *Bufo bufo* lacks such correlation between age and size in some populations characterized by older individuals but not in others with smaller and younger specimens.

The onset of maturity is generally correlated with an abrupt decline in the rate of somatic growth in anurans due to an energy drift from growth to repro-

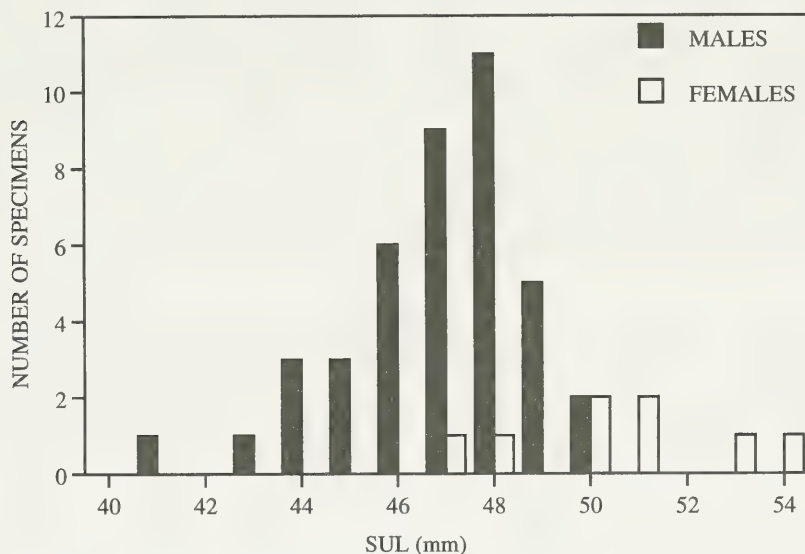


FIGURE 2. Body size (SUL: snout-urostyle length) distribution of adult *Rana sylvatica* from Kuujjuarapik.

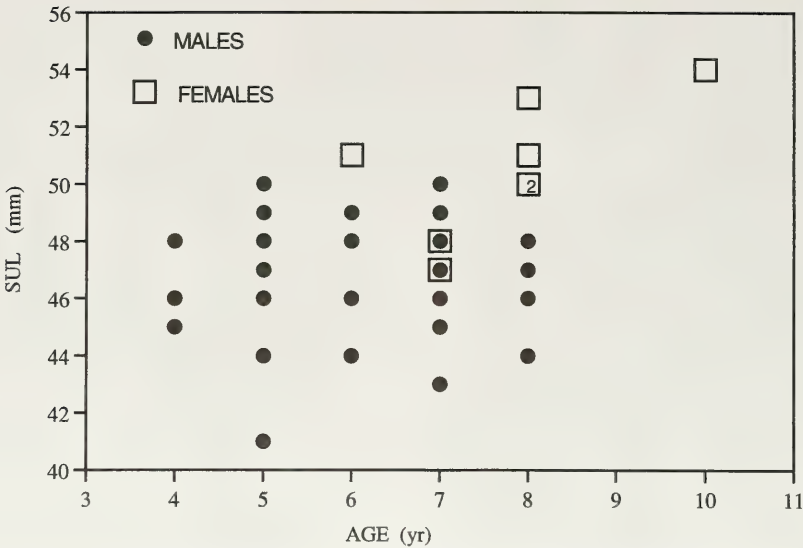


FIGURE 3. Relationships between body size (SUL: snout-urostyle length) and age in *Rana sylvatica* from Kuujjuarapik. The number in one female block indicates a double observation; many male observations are in superposition for ages 5 to 7.

duction (Ryser 1989; Jørgensen 1986). This decline in growth influences the spatial arrangement of LAGs in bone cortex. Kleinenberg and Smirina (1969) and Gibbons and McCarty (1983) have observed for *R. temporaria* and *Bufo bufo* that the onset of sexual maturity was related to a sudden rapprochement of LAGs. In many instances this osteological criterion was used to assess the age at maturity in amphibians (Barbault et al. 1979; Caetano et al. 1985; but see Augert and Joly 1993). Most of the males in the present sample of Wood Frogs had bone cortex with the image of a high growth rate for the first four years and a sharp reduction thereafter. Thus, maturity probably does not occur before 4 years of postmetamorphic life at Kuujjuarapik. SUL of the three youngest (4 years old) mature males encountered were 45, 46 and 48 mm respectively but one 5 year-old specimen measured only 41 mm. Bone cortex in females did not show evidence of

LAG rapprochement. The youngest mature female however was 6 years old (51 mm), thus, it may be postulated that females delay reproduction relative to males and continue to grow at a high rate for an additional two years. Size at metamorphosis is unknown for the study population and, in the absence of a correlation between age and size, growth rates could not be calculated. Martof and Humphries (1959) had determined that the largest Wood Frogs occur in the southern Apalachians (mean SUL of 66.8 mm for females and 54.8 mm for males from Georgia-North Carolina) and concluded that north of this area body size gradually decreased. The smallest adult Wood Frogs they encountered (mean SUL about 37.7 mm) came from northern Manitoba, northern Saskatchewan and the adjacent part of the Northwest Territories. However, when we compare studied populations from lowland localities in the eastern part of the range (Maryland,

TABLE 1. Mean snout-urostyle length (SUL), age, and physiological longevity (MPL: mean age in years multiplied by number of frost-free days per year) in different populations of Wood Frogs, *Rana sylvatica*.

Population	Frost-free days/year	SUL (mm)		Mean age (years)		MPL (days)	
		Males	Females	Males	Females	Males	Females
Kuujjuarapik	65	47.1	50.9	6.1	7.7	397	504
Trois-Rivières ^a	130	43.6	49.6	2.8	3.2	364	416
Montreal ^b	137	43.6	48.8	2.49	2.76	341	378
Maryland ^c	177	41.7	47.7	1.7	2.4	290	421
Virginia ^c	121	55.3	64.4	3.6	3.8	438	458

^aFrom Bastien and Leclair (1992); ^bSagor et al. (1998); ^cBerven (1982)

Montreal, Trois-Rivières, Kuujjuarapik), we observe an *increase* in body size of Wood Frogs with increasing latitudes (Table 1); the phenomenon is more evident in males. An European vicariante species, *R. temporaria*, is also known to increase in size with both latitudes and altitudes (Miaud and Guyétant 1998). The increase in body size in *R. sylvatica* is accompanied by a more than three-fold increase in mean age (calendar years; Table 1). Although smaller, specimens from Kuujjuarapik are twice as old as those of upland Virginia. Our results are thus consistent with the general observation that for ectotherms longer life spans are favored at low temperatures (review in Sohal 1976; Caetano and Castanet 1993; Ryser 1996).

Differences in age are tempered when this parameter is expressed as mean physiological longevity (Table 1). Male Wood Frogs from Kuujjuarapik show a lower physiological longevity (397 days) than males from Virginia (438 days). We can observe that geographic differences in Wood Frog body size, at least in males, are closely related to physiological longevity (Figure 4). However, with the assumption of sexual maturity at 4 years in males from Kuujjuarapik, we were expecting a much higher longevity for these animals. This last result contradicts the Bastien and Leclair (1992) hypothesis of a negative trade-off between early age at maturity and physiological longevity. Yet, with a maturity at 4 years and a mean age of 6 years, most of the male Wood Frogs in Kuujjuarapik could participate at

least in three reproductive seasons. Much longer reproductive lifespan may not be selected for. Berven (1990) estimated that 84% of the male and 86.8% of the female Wood Frogs in Maryland contribute to only one reproductive season. A similar increase in iteroparity with latitudes and altitudes in *R. temporaria* is viewed as a compensation for lower fecundity (Miaud and Guyétant 1998).

Among the lowland populations, female Wood Frogs from Kuujjuarapik have the highest physiological longevity (504 days) and the largest body size, but they stay definitely smaller than their conspecifics from upland Virginia (Table 1). Physiological longevity then does not explain geographical variation in female Wood Frog body size (Figure 4).

When decreasing temperatures reduce growth rate in ectotherms, models predict that larger adult body sizes are produced (Atkinson 1994). Our results seem consistent with this prediction although we do not have direct observation on Wood Frog growth rate at Kuujjuarapik. Comparative demography of *R. sylvatica* has shown that growth rate does not passively follow ambient temperatures but is genetically adapted to specific environmental conditions (Berven 1982). From the data of Berven (1982) on mean size of male Wood Frogs at specific ages, size at transformation, and number of frost-free days, we can conclude that juvenile growth rate is equal (ca 0.14 mm/day; Appendix 1) in lowland Maryland and upland Virginia, although mean temperatures are

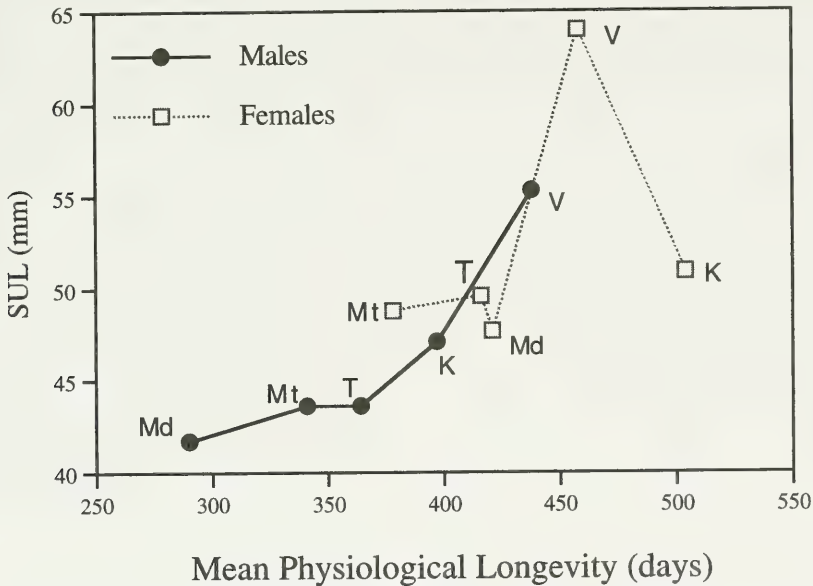


FIGURE 4. Plot of mean snout-urostyle length (SUL) against mean physiological longevity in adult Wood Frogs from different populations. K: Kuujjuarapik, Md: Maryland, Mt: Montreal, T: Trois-Rivières, V: Virginia (see Table 1 for references).

5°C lower in the uplands. Thus, growth rate appears to compensate for differences in temperature in these frogs. A higher per day growth rate during the active season may characterize Wood Frogs from northern or cold localities.

Such compensation phenomena are more frequently observed in anuran *embryonic* development where the physiological processes of growth appear temperature-adapted (review in Rome et al. 1992). In transformed animals, the compensation may have a physiological and/or behavioral components. Martof and Humphries (1959) found, for example, that Wood Frogs from Alaska-Yukon area were gorged with food, their stomachs usually distended due to their extensive feeding. Mink Frogs (*R. septentrionalis*) from northern latitudes were also found to have greater stomach contents, a higher per day growth rate, and larger body size compared to Mink Frogs from more southern regions (Leclair and Laurin 1996).

Although growth rate may be compensated, or even meliorated in cold environments, the growing season may be so short that more time (in years) is required to reach an appropriate reproductive size. Female Wood Frogs from Kuujuarapik apparently require six calendar years to reach a minimum reproductive size. Any reproductive advantages of larger size (such as increased fecundity or larger eggs) may be constrained by the likelihood of survival to the next breeding period (Pace 1974). Nevertheless, females with the highest physiological longevity from Kuujuarapik should have reached the largest body size. Perhaps to quantify physiological longevity we should use the number of degrees-days in a specific environment instead of the number of frost-free days per year in order to take into account the amount of heat available to an animal during an active season.

In summary, although our sample of Wood Frogs from Kuujuarapik is small, we can conclude that, relative to males, females have a larger body size, longer postponed maturity, and a higher mean age and longevity. Such sexual differences in these demographic parameters appear characteristic of the species although some variations in amplitude exist between populations (Berven 1982; Bastien and Leclair 1992; Sagor et al. 1998; present study). Postponed maturity in female Wood Frogs may allow for a longer period of high growth rate. Our result of an increasing adult body size with increasing latitudes for lowland Wood Frogs in the eastern part of the range contradicts the conclusions of Martof and Humphries (1959) based on museum material. This increase in body size with latitudes is partially explained by a parallel increase in mean age (calendar years). Age expressed as physiological longevity can also explain larger sizes in upland male populations; it does not appear related to age at sexual maturity, however, contrary to an earlier

hypothesis. Physiological longevity is also variable among female populations but does not show any obvious relation with mean adult body size.

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APPENDIX 1. Growth rate of Wood Frogs, *Rana sylvatica*, based from the data of Berven (1982).

Body size at transformation

- Lowland Maryland Residents: 14.9 mm (3 samples, 221 animals)
- Upland Virginia Residents: 18.6 mm (4 samples, 1049 animals)

Male juvenile growth rate

- Lowland Maryland Residents (most frogs are mature at 1 year):
mean body size at age 1 less mean body size at transformation divided by the number of frost-free days per year, or
(40.2 mm–14.9 mm) / 177 days = 0.143 mm/day
- Upland Virginia Residents (most frogs are mature at 2 years):
mean body size at age 2 less mean body size at transformation divided by the number of frost-free days per year, or
(54.7 mm–18.6 mm) / (2 × 121 days) = 0.149 mm/day

Home Range, Habitat Selection, and Survival of Bobcats, *Lynx rufus*, in a Prairie Ecosystem in Kansas

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Kamler, Jan F., and Philip S. Gipson. 2000. Home range, habitat selection, and survival of Bobcats, *Lynx rufus*, in a prairie ecosystem in Kansas. *Canadian Field-Naturalist* 114(3): 388–394.

Ten Bobcats (*Lynx rufus*), five males and five females, were radio-collared and monitored in a prairie ecosystem in north-eastern Kansas from October 1995 to March 1998 to determine seasonal home range sizes, seasonal habitat selection, and survival. Home ranges of resident Bobcats overlapped among and between sexes, and sizes of home ranges did not differ between seasons. The composite home range of a resident male (20.0 km^2) was more than twice as large as resident females ($7.5 \pm 0.8 \text{ km}^2$). Transient Bobcats had much larger ($57.1 \pm 15.8 \text{ km}^2$) and less well defined home ranges, whereas kittens had the smallest home ranges ($7.0 \pm 3.5 \text{ km}^2$). Resident Bobcats preferred grasslands in summer despite their lack of adaptations for open areas. In winter, resident Bobcats preferred woodlands possibly because of reduced food resources and greater competition with other predators. Transient Bobcats and a male kitten tended to avoid habitats that were preferred by resident Bobcats. Annual survival for resident Bobcats (1.00) was more than twice as high as for transient or dispersing Bobcats (0.46).

Key Words: Bobcat, *Lynx rufus*, home range, habitat selection, prairie, survival, Kansas.

Little is known concerning how Bobcats (*Lynx rufus*) utilize prairie ecosystems. It is generally thought that Bobcats prefer habitats with cover, such as rocky, brushy, or woodland terrain, to facilitate stalking and ambushing of prey (Kleiman and Eisenberg 1973; McCord and Cardoza 1982), and most research on Bobcats has occurred in these types of terrain (Bailey 1974; Fuller et al. 1985; Rolley and Warde 1985; Litvaitis et al. 1986; Koehler and Hornocker 1989). Despite their apparent lack of adaptations for open areas, Bobcats reportedly range over most of the prairie biome in North America (McCord and Cardoza 1982), although little published information exists describing home ranges, habitat selection, and survival of Bobcats that occur in prairie-dominated areas.

Bobcats have been classified in their social organization as resident, transient, and kitten (Bailey 1972; Anderson 1987b). Resident Bobcats are adults with stable home ranges. Transients are usually young (juvenile or yearling) Bobcats that have dispersed from their natal home range and have much larger home ranges than residents. Kittens are young Bobcats that have not yet dispersed from their natal home range (Bailey 1972; Rolley 1983; Anderson 1987b). Although different social classes of Bobcats have been described, few studies have compared the home ranges, habitat selection, and survival among the different social classes.

We report on the seasonal home ranges, seasonal habitat selection, and survival of Bobcats utilizing a tall grass prairie ecosystem in northeastern Kansas,

and compare these parameters among the different social classes of Bobcats.

Study Area

This study was conducted on Fort Riley Military Reservation in Geary, Riley and Clay counties, Kansas (39°N , 97°W). Fort Riley is a 40 273 ha permanent U.S. Army Forces Command installation located in the Flint Hills Region of northeastern Kansas. The vegetative community is dominated by tall and mixed grass prairie, interspersed with woodlands along the floodplain and within the lowlands of small drainages and ravines (U.S. Army 1994*). Major grasses include Big Bluestem (*Andropogon gerardii*), Indian Grass (*Sorghastrum nutans*), Switchgrass (*Panicum virgatum*), Little Bluestem (*Scizachyrium scoparium*), and Sideoats Grama (*Bouteloua curtipendula*) [U.S. Army 1994*]. Woodlands within small stream valleys and ravines are dominated by Bur Oak (*Quercus macrocarpa*), Chinkapin Oak (*Quercus muhlenbergii*), American Elm (*Ulmus americana*), Red Mulberry (*Morus rubra*), Bitternut Hickory (*Carya cordiformis*), Black Walnut (*Juglans nigra*), Green Ash (*Fraxinus pennsylvanica*), Hackberry (*Celtis occidentalis*), and Honey Locust (*Gleditsia triacanthos*): [U.S. Army 1994*]. All Bobcats were captured in a 250-ha area in the southern region of Fort Riley. Bobcats were

*See Documents Cited section.

trapped in this limited area to increase the likelihood that study animals would share the same habitats and interact with each other.

Fort Riley has a temperate continental climate characterized by hot summers, cold dry winters, moderate winds, low humidity and a pronounced peak in rainfall late in the spring and in the first half of summer (U.S. Army 1994*). Mean daily temperatures in January and July are 4.2°C and 33.7°C, respectively. Mean daily low temperatures in January and July are -7.8°C and 19.5°C, respectively. Mean annual precipitation is 80.4 cm, and has ranged from 40.6 cm to 142.2 cm over the past 90 years (U.S. Army 1994*).

Fort Riley has been opened to public hunting since 1982, although trapping is prohibited. Hunters must check in on a daily basis and report all animals harvested. Bobcats are not frequently harvested on Fort Riley, and no harvests were reported during the three years of this study.

Methods and Materials

We captured 11 Bobcats 17 times during two periods: October 1995–March 1996, and October 1996–March 1997. Bobcats were captured with Number 3 Victor Soft Catch® traps (Woodstream Corp., Lititz, Pennsylvania 17543, USA) equipped with the Paws-I-Trip™ pan tension system (M-Y Enterprises, Homer City, Pennsylvania 15748, USA). Trap sets were baited with a variety of baits, urines, and lures. Traps were checked twice daily to ensure that animals would not be in the trap > 12 hours. Bobcats were immobilized with an intramuscular injection of ketamine hydrochloride and acepromazine (10:1 ratio; dosage = 1 ml / 5 kg). We recorded the following data for all captured Bobcats: weight, body length, tail length, ear length, hindfoot length, shoulder height, sex, reproductive condition, age class, ear tag number, injuries, and ectoparasite load. At time of capture, Bobcats were classified as adult (> 18 months) or juvenile based on body size, reproductive condition, and tooth replacement (Crowe 1975).

Bobcats were classified as resident if they were adult and exhibited fidelity to an area for > 1 yr. Bobcats were classified as transient if they travelled in erratic, nomadic patterns in relatively large areas (> 30 km²). In most cases, this occurred after young Bobcats dispersed from their natal home ranges. Bobcats were classified as kitten if they were juvenile and had not yet dispersed from their natal home ranges. Radio-transmitter collars (Advanced Telemetry Systems, Inc., Isanti, Minnesota 55040, USA) were placed on 10 Bobcats of different sex and age groups.

Radio-tracking occurred during two periods: April to September 1996, and April 1997 to March 1998. Independent telemetry locations for each Bobcat were recorded 1–2 times per week throughout both

study periods. Locations were considered independent if they were more than 12 hours apart (White and Garrott 1990). Radio-tracking was performed using null-peak systems which consisted of dual, 4-element Yagi antennas mounted on two vehicles. A small number of aerial locations were obtained for Bobcats that could not be located on the ground.

Radio-tracking occurred in four overlapping shifts of 6-hour blocks. The times of the shifts were 1800–2400, 2100–0300, 2400–0600, and 0300–0900 hours. Each study animal was located four times, once in each shift, during every two-week period. Radio-tracking effort was concentrated from 1800–0900 hours to obtain locations of study animals when they were most active. Additionally, study animals were located at least once a month during 0900–1800 hours to determine daytime resting sites.

Animal locations were determined from azimuth angles of 40–140, made from simultaneous readings from ≥ 2 telemetry stations (White and Garrott 1990). The locations or point estimates, were calculated using the maximum likelihood estimation (MLE) option in the computer program Locate II (Pacer, Inc., Truro, Nova Scotia). More than 100 telemetry stations were used during the study, and station locations were verified using a global positioning system (GPS) unit (Trimble Navigation Limited, Sunnyvale, California 94086 USA). Telemetry errors, determined for each antenna system, were based on 297 readings of test collars placed in 79 different locations. Locations of test collars were verified using a GPS unit. Mean telemetry error (White and Garrott 1990) was ±3.3° and ±4.3°, respectively, for the telemetry systems mounted in the two vehicles.

Radio-telemetry data were analyzed in two seasons defined as summer (April–September) and winter (October–March). The two seasons were defined in this way to parallel major changes in climate and animal responses to climatic change, and to increase the sample size per season. Seasonal and composite sizes of home ranges of Bobcats were determined using the 95% minimum convex polygon (MCP) method (Mohr 1947), as calculated by CALHOME (Kie et al. 1994). Seasonal home ranges were calculated for study animals with at least 20 locations and 3 months of radio-tracking per season. Composite home ranges were calculated for study animals if they remained in the same social class and were monitored during both defined seasons.

Habitat types were delineated using geographic information system (GIS) data provided by the Conservation Division at Fort Riley. Habitat types on Fort Riley were classified at 2 m resolution as grassland, woodland, built areas, water, and sandy areas (Lauver et al. 1996*). Grassland was defined as all pasture (hayfield), rangeland, and other herbaceous cover having insufficient trees and/or shrubs

to be classified as “woodland.” Woodland was defined as wooded areas with greater than 15% canopy closure. Built areas were defined as areas of intensive use with much of the land covered by structures. Water was defined as all water bodies larger than the minimum mapping unit of 2 m. Sandy areas were defined as river sand bars, rock quarries, sand and gravel pits and other permanently exposed ground (Lauver et al. 1996*). The placement of land cover boundaries had a spatial accuracy of ±10 m (Lauver et al. 1996*). Total coverage of these habitat types on Fort Riley was 82% grassland, 16% woodland, 2% built areas, and a trace of both water and sandy areas. Total coverage of the 250 ha trapping area consisted of 62% grassland, 37% woodland, and 1% built areas (Kamler 1998).

Habitat selection (based on habitat types used in relation to habitat types available to each animal) was the focus of analysis for this study, as opposed to overall habitat use (based only on habitat types used), since Bobcat home ranges were not uniform in habitat types within and between adjacent animals. Habitat selections were determined using the computer program ArcView GIS (Version 3.0, Environmental Systems Research Institute, Inc., Redlands, California 92373).

To determine habitat selections for each Bobcat, a selection index was calculated by dividing the observed number of locations by the expected number of locations for each habitat type. The expected number of locations for each habitat type was calculated as: (total number of locations inside home range) × (proportion of home range consisting of that habitat). A habitat selection index > 1 indicated a preference for that habitat type, and an index < 1 indicated an avoidance for that habitat type. We used a Wilcoxon rank sum test (SAS Institute 1985) to determine if mean habitat selection indices of resident Bobcats differed between seasons. Preliminary analyses showed that the resident male had habitat selection indices that were similar to adult females, and therefore both genders were pooled for both seasons. Only selection indices for grassland habitat were used to determine statistical differences because it was the most dominant habitat type in the

study area. Statistical tests using additional habitat types would not be independent since the study area was dominated by only two habitat types, grassland and woodland.

Survival rates were determined using MICRO-MORT (Heisey and Fuller 1985). Preliminary analyses showed that resident survival rates did not differ among years, and therefore residents were pooled for all years. Survival rates of transients did not differ among years and were also pooled. Survival rates were not calculated for kittens because of insufficient data. Differences in survival rates were deemed significant when $P < 0.05$ with Z-tests (Nelson and Mech 1986). Biological time intervals used in survival analyses were summer (April–September) and winter (October–March).

Results

Home ranges

There was sufficient data to calculate home ranges for six Bobcats (4 residents, 2 kittens) (Table 1). Both kittens dispersed after the first season of being monitored, and subsequently were monitored as transients during their second seasons (Table 1). Additionally, a transient male Bobcat was located 7 times, which encompassed a minimum area of 51.5 km², and a male kitten was located 11 times, which encompassed a minimum area of 3.7 km², before he dispersed.

Mean home range sizes of resident female Bobcats were similar among seasons ($P > 0.05$) (Table 1). However, individual home ranges of resident female Bobcats varied considerably more during both summers than winter (Table 1). The summer home range of the resident male varied little from his winter home range.

The two transient Bobcats (1 male, 1 female) had the largest home range sizes. In contrast, home range sizes of the two kittens (1 male, 1 female) were smaller than those of resident Bobcats of the same sex (Table 1).

Home ranges of two of the three resident females overlapped almost completely during all seasons (Figure 1). The home range of a resident male overlapped most of the home range of one resident

TABLE 1. Home range sizes^a (km²) of different social classes of Bobcats (*Lynx rufus*) monitored on Fort Riley Military Reservation, Kansas, 1996–1998.

Social class	Summer 1996 home range (km ²)		Summer 1997 home range (km ²)		Winter 1997–1998 home range (km ²)		Composite home range (km ²)	
	<i>n</i>	Mean ± SE	<i>n</i>	Mean ± SE	<i>n</i>	Mean ± SE	<i>n</i>	Mean ± SE
resident male		NA	1	16.4	1	16.5	1	20.00
resident female	3	5.7 ^b ± 0.4	3	5.9 ^b ± 0.7	3	5.8 ^b ± 0.03	3	7.5 ± 0.5
kitten	1	4.5	1	9.5		NA		NA
transient		NA	1	45.9	1	68.2		NA

^aCalculated using 95% minimum convex polygon method.

^bMean home range sizes of resident females did not differ among seasons ($P > 0.05$).

female in both seasons (Figure 1). The home ranges of both a female kitten in summer 1996, and a male kitten in summer 1997 (Figure 1), included part of the home range of their mother before they dispersed and became transients.

Habitat selection

There was sufficient data to calculate habitat selection indices for six Bobcats (4 residents, 2 kittens) (Table 2). As stated earlier, both kittens dispersed after the first season of being monitored, and subsequently were monitored as transients during their second seasons (Table 2). Resident Bobcats selected grassland habitats more than available in both summers, and less than available in winter (Table 2). Resident Bobcats had a mean habitat selection index for grassland that was significantly less in winter 1997–1998 (0.87) than both summers 1996 (1.12) and 1997 (1.12) ($P < 0.05$; Table 2). Although the resident male had habitat selections that were similar to resident females, he had an overall higher use of grassland habitat than the three females in both summer and winter (Kamler 1998). Habitat selection indices of Bobcats were relatively consistent despite the availability of grassland habitat in individual home ranges varying

from 39–78% in summer and 36–79% in winter (Kamler 1998).

A female kitten monitored in summer 1996 had habitat selection indices that were similar to resident Bobcats (Table 2). However, a male kitten monitored in summer 1997 selected grassland habitats less than available, and had the highest selection of any Bobcat for woodland habitats (Table 2). The two transients, monitored in different seasons, had similar habitat selections and selected grassland habitats more than available, and selected woodland habitats less than available. However, both transients had the overall highest use of grasslands (i.e., 95% and 89% of locations) and lowest use of woodlands (i.e., 5% and 6% of locations) (Kamler 1998).

Survival

Annual survival rates for resident Bobcats (1.00) was greater than transient Bobcats (0.46) ($Z = 3.01$, $P < 0.005$). There was one study-related death of an adult male Bobcat that was deleted from the survivor rate estimates. Four transient Bobcats died during the study. All four deaths were related to human activity and occurred beyond the boundary of Fort Riley. Two Bobcats were harvested by trappers, one was shot, and one died from a vehicle collision.



FIGURE 1. Home ranges of radio-collared Bobcats in summer 1997 on Fort Riley Military Reservation, Kansas; similar patterns were also observed in other seasons and years (Kamler 1998); solid polygons represent resident females ($n = 3$), dashed polygons represent a resident male (A) and a male kitten (B); solid rectangle represents 250 ha trapping area.

TABLE 2. Habitat selection indices^a for Bobcats monitored on Fort Riley Military Reservation, Kansas, April 1996–March 1998.

Social class		Grassland Index	Woodland Index	Built areas Index
Summer 1996	<i>n</i>	Mean \pm SE	Mean \pm SE	Mean \pm SE
Resident ^b	3	1.12 ^c \pm 0.08	1.05 \pm 0.17	NA
Kitten	1	1.10	0.75	0.00
Summer 1997	<i>n</i>	Mean \pm SE	Mean \pm SE	Mean \pm SE
Resident ^b	4	1.12 ^c \pm 0.05	1.02 \pm 0.16	NA
Kitten	1	0.80	3.18	0.59
Transient	1	1.03	0.63	0.00
Winter 1997–1998	<i>n</i>	Mean \pm SE	Mean \pm SE	Mean \pm SE
Resident ^b	4	0.87 ^c \pm 0.05	1.49 \pm 0.25	NA
Transient	1	1.05	0.60	1.20

^aCalculated by dividing the percentage of that habitat type used by the percentage of that habitat available (See Methods); habitat selection indices >1 indicate a preference for the habitat type, and indices <1 indicate avoidance.

^bResident class consisted of 3 adult females in summer 1996, and 3 adult females and 1 adult male in both summer 1997 and winter 1997–1998.

^cMean grassland habitat selection indices differed between summer and winter ($P < 0.05$).

Discussion

Home ranges of female Bobcats reportedly have varied from > 40 km² in California (Zezulak and Schwab 1979), Idaho (Koehler and Hornocker 1989; Knick 1990) and Minnesota (Fuller et al. 1985), to 1–2 km² in Alabama (Miller 1980), Louisiana (Hall and Newsom 1976), Oregon (Witmer and deCalesta 1986) and Texas (Bradley and Fagre 1988). In general, home ranges of Bobcats tend to be larger in more northern latitudes (Anderson 1987b). On Fort Riley, resident female Bobcats had relatively small composite home ranges (7.5 km²). The smaller home ranges found elsewhere may be the result of more abundant prey, and/or that Bobcat body sizes are smaller, and therefore energy requirements are correspondingly smaller, in more southern latitudes and western coastal areas (Anderson 1987b).

Home range size of Bobcats may also be strongly related to prey abundance and availability (Bailey 1972; Buie et al. 1979; Litvaitis et al. 1986). Female Bobcat home ranges have been shown to increase over time as prey populations decrease (Marshall and Jenkins 1966; Buie et al. 1979; Knick 1990). On Fort Riley, Bobcat diets were not determined, but the primary prey of Bobcats throughout their range are lagomorphs, which in some areas occur in over 90% of their diets (Anderson 1987b). Eastern Cottontails (*Sylvilagus floridanus*) were abundant on Fort Riley (Kamler 1998), which may have contributed to the relatively small home ranges of female Bobcats.

Bobcats are known to exhibit sex-related dimorphism, with males generally at least 25% larger than females (Anderson 1987b), but in some cases up to 80% larger (Litvaitis et al. 1984). Several researchers have found that these size discrepancies led to the exploitation of different sized prey by males and females, thus reducing intraspecific competition for food resources (Fritts and Sealander 1978; Sweeney 1978; Litvaitis et al. 1984). Males are also known to have home ranges that are 2–3 times larger than females, and in some areas up to 5 times larger than females. The composite home range of the resident male in this study was 2.5–3 times larger than the mean composite home range of females. This difference probably was not explained by the energetic demands of body size (11.1 kg), which was only 34% larger than the mean body size of females (8.3 \pm 0.2 kg). The likely reason for these discrepancies is that female home ranges are more influenced by prey abundance and energetic demands, whereas male home ranges are more influenced by breeding opportunities (Bailey 1972; Anderson 1987b; Sandall 1989). Therefore, home range sizes of females should be of a size that adequately meets their energetic requirements, which includes raising young, whereas home range sizes of males should be at a size that encompasses as many female home ranges as possible.

Variability in home range sizes of resident females was greater during both summers than winter. We believe that these discrepancies were related to individual differences in energetic needs resulting from different litter sizes. Litter sizes of female Bobcats were not determined in this study; however, Kansas Bobcats are known to have litters ranging from 1–4 kittens, with many adult females not reproducing in a given year (Johnson and Holloran 1985). Individual differences in litter size likely result in differences in energetic needs, resulting in greater variability in home range size during summer. In winter, after kittens have become independent, resident female Bobcats should have similar energetic needs, resulting in similar sized home ranges.

Several studies have reported that Bobcat habitat use changes seasonally (Rolley 1983; Koehler and Hornocker 1989; Lovallo 1993) whereas other studies found no seasonal changes in habitat use (Hamilton 1982; Jackson 1986; Anderson 1987a). Rolley (1983), in Oklahoma, and Koehler and Hornocker (1989) in Idaho, found that Bobcats used open areas more in winter and forested areas more in summer. In contrast, all resident Bobcats on Fort Riley preferred grassland habitats, and all but one avoided woodland habitats in both summers. In winter, all resident Bobcats avoided grassland habitats and preferred woodland habitats. The habitat selections were consistent despite relatively high variability in the amounts of different habitat types within individual home ranges.

Our data indicate that resident Bobcats in Kansas prefer grassland habitats, at least during certain times of the year, despite their apparent lack of adaptations for use of open areas. Resident Bobcat preference for grasslands in summer may have been due to a greater diversity, and possibly higher abundance, of small mammals in grasslands than woodlands (Kaufman and Fleharty 1974). In winter, there was probably greater competition with other predator species for limited food resources, and therefore Bobcats may have preferred woodland habitats where they could better exploit prey utilizing their adaptations for an ambush style of hunting. On Fort Riley, resident Coyotes (*Canis latrans*) preferred grassland habitats in both seasons (Kamler 1998). Coyotes can have negative impacts on Bobcat populations, possibly through direct predation (Linhart and Robinson 1972; Nunley 1978; Jackson 1986; Toweill 1986). Therefore, Bobcats may need to avoid Coyotes more in winter, when competition for food resources between the two species is greatest (Kamler 1998). Coyotes may have been more tolerant of Bobcats in summer when Coyotes had a more varied diet and food resources were more abundant (Kamler 1998). The resident male Bobcat used grasslands more than resident females in both seasons, possibly because his larger body size reduced his risk of predation (Anderson 1987a).

Although habitat selections of transient Bobcats were similar to residents, transients used open areas more and woodland habitats less than other Bobcats (Kamler 1998). The differences in habitat use between resident and transient Bobcats probably allowed transients to reduce contact with resident Bobcats. McCord and Cardoza (1982) stated that transients, while tolerated by resident Bobcats, do not use habitats that are preferred by resident Bobcats. Transient Bobcats apparently wander over large areas to look for vacant territories (Bailey 1972; Hamilton 1982).

A female kitten had habitat selections that were similar to resident Bobcats. In contrast, a male kitten used grassland less, and woodland and built areas more than resident Bobcats. This may indicate that young male bobcats attempt to reduce contact with resident Bobcats, especially adult males, to avoid potentially aggressive encounters with them (Kitchings and Story 1984; Anderson 1987b).

Fort Riley may have provided a refuge for Bobcats, as survival rates of residents were more than twice as high as transients. Bobcats on Fort Riley were unexploited, therefore, any residents that remained had high survival. When Bobcats dispersed from Fort Riley, they encountered hunting and trapping pressure from humans, and were probably more vulnerable because they travelled into unfamiliar areas.

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Status and Nesting Distribution of Lesser Snow Geese, *Chen caerulescens caerulescens*, and Brant, *Branta bernicla nigricans*, on the Western Arctic Coastal Plain, Alaska

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We describe the current status of nesting by Lesser Snow Geese (*Chen caerulescens caerulescens*) and Brant (*Branta bernicla nigricans*) on the western Arctic Coastal Plain of Alaska. We conducted aerial surveys along Alaska's Beaufort and Chukchi seacoasts in 1991–1998 to determine the current distribution and abundance of these two colonially nesting goose species and to monitor their status at selected colonies. Areas of optimal habitat were surveyed, so we doubt that any large colonies of either Snow Geese or Brant were missed. We obtained the first specific size and location information for two colonies of Snow Geese on the Kukpowruk and Ikpiukuk river deltas, which combined were occupied annually by a total of approximately 100 pairs. Snow Geese nested irregularly within the study area at 15 other locations that accounted for no more than 13 nests in any year. Museum records indicated that Snow Geese have nested near or at some of these sites since at least the 1930s. Brant were recorded nesting at 135 locations in the study area. The combined total number of nests (estimated by adding the highest recorded number of nests for all sites) was over 1070 (1–53 nests/location). The majority of these nests were located east of Barrow and within 10 km of the coast. Most nests were located on islets in shallow lakes and basin wetland complexes, but three colonies were located on deltaic islands. Historical information on Brant nesting locations in the region is limited.

Key Words: Snow Goose, *Chen caerulescens caerulescens*, Brant, *Branta bernicla nigricans*, distribution and abundance, nesting, Arctic Coastal Plain, North Slope, Alaska.

Two species of colonially nesting geese — Snow Goose (*Chen caerulescens caerulescens*) and Brant (*Branta bernicla nigricans*) — nest on Alaska's Arctic Coastal Plain (Pitelka 1974; Johnson and Herter 1989; Stickney and Ritchie 1996). Much of our current knowledge of their breeding status and distribution in northern Alaska comes from research to assess the potential impacts of oil exploration and development on the environment (e.g., Johnson 1991*; Stickney and Ritchie 1996), primarily on the central Arctic Coastal Plain between the Canning and Colville rivers. Consequently, less is known about the status and distribution of these species nesting on the large undeveloped portion of the coastal plain west of the Colville River. Status and distribution of colony locations of Snow Geese and Brant is essential for management of these species in the region, especially with increasing interest in oil exploration and development in northern Alaska — particularly within the National Petroleum Reserve-Alaska (NPR-A) — and the changing sta-

tus of both species in North America (e.g., Sedinger et al. 1994; Abraham and Jefferies 1997). This paper summarizes the results of aerial and ground-based surveys conducted to assess the current distribution and status of Snow Geese and Brant nesting on the western Arctic Coastal Plain of Alaska. The focus is on the incubation period, but some brood-rearing information also has been included. In addition, we have synthesized historical records of nesting by both species in the study area.

Study Area

The study area included coastal plain habitats along the Chukchi and Beaufort seacoasts between the Colville River and the western edge of Kasegaluk Lagoon, including NPR-A (Figure 1). Wetland habitats ranging from shallow *Carex* ponds to deep *Arctophila* lakes, often set in basin wetland complexes, dominate the region, especially east of Barrow (see Bergman et al. 1977 for detailed wetland descriptions). Habitats surveyed included barrier islands, river deltas, saltmarshes, mudflats, sparsely vegetated dunes, and wet tundra. Tundra areas typically were polygonized and included wet sedge meadows, wet sedge-grass meadows, and grass marshes (Vioreck et al. 1992). Surveys extended

*see Documents Cited

inland approximately 5 km in the area west of Barrow and approximately 30 km inland in the area east of Barrow, reflecting the general distribution of habitat suitable for nesting. The entire study area lies within the Arctic Climatic Zone (Hartman and Johnson 1984). A strong maritime influence extends inland several km, causing low summer temperatures, late thawing of lakes, summer fog, and strong northeasterly prevailing winds (particularly east of Barrow).

We divided the study area into five subregions, reflecting major differences in coastal physiography and habitat distribution. This division facilitated data interpretation and comparisons among years. The subregions, from west to east (Figure 1), are: (1) Kasegaluk Lagoon, including coastal spits and barrier islands and deltas along the mainland; (2) Wainwright (eastern terminus of Kasegaluk Lagoon to Barrow), including the mainland coast, spits, and inlets; (3) Barrow (Barrow to Cape Simpson), including the mainland coast, coastal spits, inlets, deltaic islands, and inland ponds and lakes; (4) Smith Bay (Cape Simpson to Pitt Point), including the mainland coast, deltaic islands, and inland ponds and lakes; and (5) Harrison Bay (Pitt Point to the western channel of the Colville River), including the mainland coast, coastal spits, inlets, deltaic islands, and inland ponds and lakes.

Methods

Aerial Surveys During Nesting

We conducted aerial surveys to identify nesting locations in 1991–1998, during the mid to late incubation period (8–25 June) for geese in the area. The extent of survey coverage, however, varied among years due to changing objectives. In 1991, we only visited the Kukpowruk River Delta in Kasegaluk Lagoon. In 1992 and 1993, we surveyed coastal areas from the Colville River Delta to Kasegaluk Lagoon. We decreased our coverage in 1994 and 1995, surveying the area between Smith Bay and Kasegaluk Lagoon. From 1996 onward, the Kukpowruk River Delta and the area between the Colville Delta and Barrow have been surveyed annually.

Nesting surveys were conducted from a fixed-wing aircraft (Cessna 185) with a pilot and one observer. The observer was responsible for all counts of geese, but the pilot assisted with locating birds and nests. The aircraft generally was flown at a speed of ~140 km/h and 50 m above ground level (agl). Colonies often were circled to afford better counts, but these overflights were limited in an effort to reduce disturbance. Data recorded for each nesting location included estimated numbers of adults and nests, a general description of the habitat (e.g., islet in lake, deltaic island), and locations (latitude, longitude) from the aircraft's Geographical Positioning System (GPS).

For Snow Geese, we estimated numbers of nests by counting the number of pairs whose members remained close together and did not fly as the air-plane passed overhead (Kerbes 1982). At the Kukpowruk and Ikpihpuk colonies, the final nest count often was obtained from ground-based searches conducted after hatch. In some years at these two colonies (Kukpowruk 1991–1993 and Ikpihpuk 1993), vertical, color aerial photographs also were taken from a belly port in the plane, to check the accuracy of the aerial count and to assist in locating nests during ground visits after hatch. Photos were taken at 500 m agl with a Pentax 6 × 7 cm format camera and a 105-mm lens, were printed in 20 × 25 cm format, and were examined with an 8× magnifier. We classified pairs on the ground as suspected nesting pairs, single birds as separated nesting pairs, and groups in flight as nonbreeders (Kerbes 1982). Precise locations of suspected nest sites were marked on a photo-mosaic for subsequent use in post-hatch, ground-based surveys.

For Brant, we estimated numbers of nests from observations of down-filled bowls or adults in incubation posture. Aerial counts of Brant nests generally represent minimal estimates because of the difficulty of identifying all nests from the air (Stickney and Ritchie 1996). Estimated numbers of Brant nests should be considered indicators of relative sizes of colonies, rather than precise counts.

After initially identifying Brant colonies in 1994, we established a monitoring protocol to determine annual occupancy and status of 45 colonies between Barrow and the Colville River. In addition, we conducted more extensive surveys annually to identify additional Brant colonies. These surveys were conducted by flying a lake-to-lake route, including selected wetlands, within a general framework of contiguous and parallel east-west corridors (<3.2 km wide; Stickney and Ritchie 1996). Suitable sites (e.g., lakes with islands, drained lakes) were noted on maps prior to flights, but additional wetlands were searched en route.

Nesting Success Surveys

We collected data on nesting success and productivity by visiting the Kukpowruk and Ikpihpuk river Snow Goose colonies after hatch, when possible. At these colonies in 1991–1993, the ground-based search often was aided by aerial photo-mosaics on which possible nests were marked. However, because of the small size of these colonies, aerial photos were not considered essential to surveys of nesting success and they were not taken after 1993. A nest was considered successful if we found at least one thickened shell membrane that was largely separated from an eggshell fragment and considered failed if a thin and papery membrane was firmly attached to eggshell fragments or if no eggshell remnants were present.

Brood-rearing Surveys

We conducted surveys for Snow Geese and Brant during the brood-rearing period in 1995 to 1997 with a fixed-wing aircraft (Piper Supercub) with a pilot and one observer. Surveys were conducted in the last week of July, when many brood-rearing groups move to coastal saltmarsh habitats (Stickney and Ritchie 1996). The aircraft was flown at a speed of ~110 km/h and 50 m agl. The aircraft circled brood-rearing groups to allow the observer to make accurate counts of adults and goslings. Because most groups were small (<50 birds), photo censuses were not necessary. Each brood location was recorded with an onboard GPS, and all locations subsequently were entered into a GIS database.

Synthesis of Historical Information

To establish the histories of Snow Goose colonies, we contacted museums that were known to house specimens from Alaska and requested specific information on the collection locations of eggs, goslings, or adults with brood patches. Additional unpublished information on nesting Brant and Snow geese was provided by biologists working in the region and by checking unpublished reports.

Results

Snow Geese

Surveys in 1991–1998 documented the locations and regular use of colonies by Snow Geese on the Kukpowruk River Delta in Kasegaluk Lagoon, on the Chukchi Sea coast, and on the Ikpihpuk River Delta, on the Beaufort Sea coast. Combined, approximately 100 pairs of Snow Geese occupied these two colonies each year. Nesting pairs of Snow Geese also were recorded at 15 other locations during these surveys (Figure 1).

Kukpowruk River Delta Colony

The colony on the Kukpowruk River Delta is located on an island ~0.5 km long (69.6087°N 163.0847°W). Nests were concentrated on the eastern half of the island, which has a vertical relief of 1–4 m and is dominated by high- and low-centered polygons. Flooded tundra and permanent ponds characterize the western half of the island.

Estimated numbers of adult Snow Geese on the Kukpowruk River Delta ranged from 10 in 1994 to 185 in 1991 (Table 1). The variation in numbers of adults may have been partly due to the later timing of visits after 1993 (i.e., counts may have occurred after non-breeders and failed breeders had abandoned the area). No blue-phase Snow Geese were observed at this colony during our surveys.

Estimated numbers of nest sites varied from 0 in 1994 to 57 in 1996 (Table 1). Photo-interpretation overestimated the count of nests at the Kukpowruk River Delta colony in 1992 and 1993 by 16–20%, based on results of ground-based searches. Misidentified sites included light colored debris and some birds, apparent-

ly non-breeders, who remained on the ground during the aerial survey. (This problem was not encountered in seven years of surveys at the larger Sagavanirktok River colony [R. Burgess, unpublished notes].) The 1991 estimate of number of nests (made from aerial photos only) may, therefore, be inflated.

Nesting success ranged from 0% (no nests successful) to 89% during the six years for which we have data from ground visits (Table 1). Causes for poor success were not determined.

Ikpihpuk River Delta Colony

The colony in the Ikpihpuk River Delta (70.8160°N 154.4987°W) occupied several small islands in the outer delta; all islands had little vertical relief. In 1992, Snow Geese used three small islands at the western edge of the delta that were dominated by low-centered polygons, brackish ponds, and wet tundra. In 1993, most nests were located on a fourth island, which consisted of a ridge surrounded by flooded polygonized tundra. This change in distribution in 1993 was attributed to flooding of much of the delta, including the three low islands that were used for nesting in 1992 (Ritchie and Burgess 1993*). No nests were recorded on the colony islands in 1996, but nests were recorded for the first time at some dispersed inland sites.

We recorded 0–200 adult Snow Geese on islands in the Ikpihpuk River Delta during aerial surveys in

TABLE 1. Numbers of adults, minimal colony size, and estimates of nesting success for Snow Geese on the deltas of the Kukpowruk and Ikpihpuk rivers, Alaska, 1991–1998.

Location	Year	Number of		Nesting success (%)
		Adults ^a	Nests ^b	
Kukpowruk	1991	185	55 ^c	nd ^e
	1992	130	26 ^b	8
	1993	135	44 ^b	89
	1994	10	0	nd
	1995	68	36 ^b	11
	1996	nd	57 ^b	65
	1997	nd	35 ^b	0
	1998	nd	46 ^b	4
Ikpihpuk	1991	nd	nd	nd
	1992	200	43 ^d	7
	1993	140	42 ^b	21
	1994	20	5 ^c	nd
	1995	200	55 ^c	nd
	1996	0	0	nd
	1997	160	50 ^c	nd
	1998	195	nd	nd

^aEstimate of pairs and single birds on the ground + birds in flight.

^bDetermined during ground-based surveys.

^cEstimate from aerial survey only.

^dProbably represents 50% of nests in the region because only one of three nesting islands was searched; no photos were taken in 1992.

^end = no data

TABLE 2. Distribution and composition of Snow Goose and Brant groups during brood-rearing surveys, western Arctic Coastal Plain, Alaska, July 1995–1997.

Species	Subregion	Number of Adults (Number of Goslings)						\bar{x} (SD)		
		1995		1996		1997		Number of Adults		Number of Young
Snow Goose	Kasegaluk Lagoon	10	(10)	—	—	—	—	—	—	—
	Wainwright	0	(0)	—	—	—	—	—	—	—
	Barrow	23	(39)	3	(6)	5	(8)	10	(11)	18 (19)
	Smith Bay	154	(164)	67	(6)	108	(127)	110	(44)	99 (83)
	Harrison Bay	21	(29)	100	(73)	369	(3)	163	(182)	35 (35)
	Total ¹	208	(242)	170	(85)	482	(138)	283	(173)	152 (74)
Brant	Kasegaluk Lagoon	1201	(57)	—	—	—	—	—	—	—
	Wainwright	0	(0)	—	—	—	—	—	—	—
	Barrow	543	(278)	1022	(227)	1398	(100)	988	(429)	202 (92)
	Smith Bay	550	(65)	305	(38)	650	(39)	502	(178)	47 (15)
	Harrison Bay	1639	(566)	631	(368)	1703	(284)	1324	(601)	406 (145)
	Total ¹	3933	(966)	1958	(633)	3751	(423)	2814	(899)	655 (244)

¹Mean numbers of adults and young exclude Kasegaluk Lagoon totals in 1995.

June 1992–1998 (Table 1). Between-year differences in numbers may be partly due to differences in the timing of surveys. No blue-phase Snow Geese were observed on the Ikpiukuk River Delta in any year, but a pair of blue-phase adults with a brood was seen near the colony in 1994.

Estimates of the number of nests ranged from 0 to 55 between 1992 and 1997 (Table 1). Again, photos were useful in identifying the extent of nests, but only 91% of possible nest sites (e.g., pairs) identified on photos were determined to be actual nests on the ground survey.

Nesting success (21%) for the entire Ikpiukuk colony was determined only for 1993, when we visited and searched the entire colony. Although no ground visits occurred after 1993, intensive searches for broods in 1995 and 1997 suggested high nesting success in those years, based on the number of broods and the ratio of goslings to adults in the area (Table 2). Numerous adults and goslings also were reported in this region in 1998 (S. Hamilton, Arctic Air Alaska, personal communication.).

Other Nesting Locations

Snow Geese were observed at numerous other locations during aerial surveys in June 1992–1998; nesting

birds were recorded at 15 of these sites (Figure 1). Most of these locations (87%) used by Snow Geese also were occupied by nesting Brant. Single adult blue-phase geese were recorded in 1996 at two locations between Dease Inlet and the Ikpiukuk River Delta. Generally, nest sites were scattered or in small colonies (<13 nests) and rarely were occupied in more than one survey year, although three general areas were occupied in at least two years. Eight of these nest locations were identified only in 1996, when the Ikpiukuk colony was not used; hence, they may have represented alternative sites for pairs regularly nesting on the Ikpiukuk River Delta. Nesting habitats used by Snow Geese at these dispersed locations included small patches of tundra on mudflats, strangmoor (i.e., linear peat material) ridges, and islands and mounds associated with basin wetland complexes.

Distribution and Abundance of Brood-rearing Snow Geese

Counts of Snow Geese between Barrow and the Colville River Delta averaged 283 adults and 152 goslings, 1995–1997 (Table 2). Most brood-rearing groups were recorded on saltmarsh habitats in the Smith Bay area near the Ikpiukuk River Delta colony. Brood-rearing surveys were conducted west of

TABLE 3. Occupancy rates and numbers of nests by subregion of 45 Brant colonies that were monitored annually, Barrow to Fish Creek, Alaska, 1994–1998.

Subregion	Colonies				Nests		
	Number	Number Occupied/y	Average Number Occupied	Average % Occupied/y	Range	\bar{x}	SD
Barrow	37	19–33	25	68	119–208	174	38
Smith Bay	6	3–5	4	67	42–52	46	4
Harrison Bay	2	2	2	100	40–73	62	15
TOTAL	45	24–40	31	69	171–324	270	60

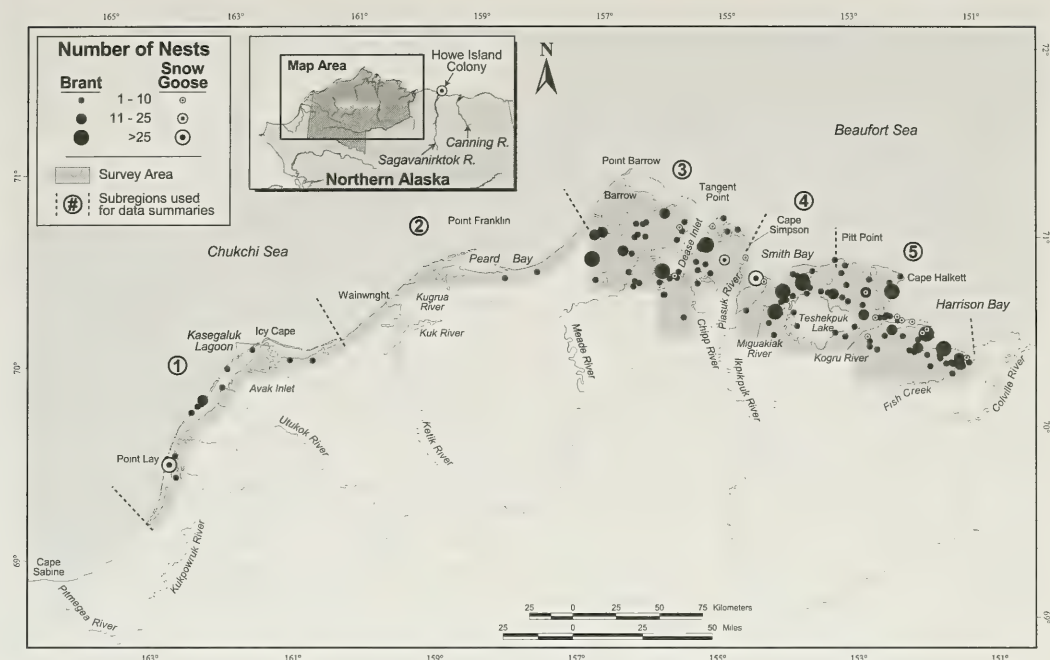


FIGURE 1. Study area and distribution and size of colonies of Snow Geese and Brant identified during aerial surveys, western Arctic Coastal Plain, Alaska, 1991–1998.

Barrow only in 1995; 10 adults and 10 goslings were observed in Kasegaluk Lagoon (Ritchie 1996*).

BRANT

Colony and Nest Distribution

Between 1994 and 1998, we identified 135 nesting locations for Brant between Kasegaluk Lagoon and the Colville River (Figure 1). Most sites (87%) were in small clusters between Barrow and Fish Creek, but a few sites (11%) occurred on gravel spits and islands in Kasegaluk Lagoon. Brood-rearing surveys indicated the same general pattern of distribution, in that many Brant goslings were observed in saltmarsh habitats east of Barrow, but few were seen west of there. Nest sites were located up to 27 km inland, but most (76%) were within 10 km of the coastline (\bar{x} = 6.5 km, SD = 6.3).

Brant were most often found nesting on islands and mounds in shallow lakes and basin wetland complexes. Only three nesting locations (containing <10% of all Brant nests) were identified on well-defined deltaic islands on the Meade, Ikpihpuk, and Miguakiak rivers. In the Kasegaluk Lagoon area, most Brant nested on small vegetated portions of the outer spit or on small islands within the lagoon itself.

Nest Abundance and Colony Occupancy

Number of nests per site ranged from 1 to 53 (\bar{x} = 8.0, SD = 10.2). Most locations (81%) had 1–10

nests, whereas only 15 (11%) were medium-sized colonies (i.e., 11–25 nests). Most nests (94%) were located east of Barrow, reflecting the greater number of nesting locations and the higher average number of nests per location in this portion of the study area (Figure 1). At 45 sites (>2 nests/site) that we monitored annually between 1994 and 1998, occupancy (presence of Brant nests) averaged 69% (range 53–89%) (Table 3).

Distribution and Abundance of Brood-rearing Brant

Although nesting success was not assessed directly, brood-rearing surveys in July provided a relative measure of productivity in each subregion (Table 2). A complete census of the coastline between Kasegaluk Lagoon and the Colville River Delta in 1995 recorded 4899 Brant, of which nearly 20% were goslings. Numbers of Brant adults and goslings averaged 2814 and 655, respectively, for the coastal area between Barrow and the Colville River Delta between 1995 and 1997 (Table 2). Brood-rearing Brant were most numerous in the Harrison Bay area, primarily in saltmarshes between the Kogru River and the Fish Creek. Additional saltmarshes between the mouth of the Chipp River and the western side of the Ikpihpuk River Delta also were used regularly by Brant.

General observations suggested that the availability of preferred nesting and brood-rearing habitats is limited in the study area west of Barrow. Surveys in

these subregions were conducted only in 1995 and identified over 1200 molting adult Brant and 57 goslings. However, large flocks, composed mostly of nonbreeders, were recorded there during June 1991 and 1992 visits to monitor use of the Kukpowruk Snow Goose colony.

Discussion

SNOW GEESE

Before the 1930s, Snow Geese were reported to be "common breeders" along portions of the northern coast of Alaska (Bailey 1948; Gabrielson and Lincoln 1959). Bailey et al. (1933) reported Snow Geese as common near Barrow, and eggs or young were taken by collectors in 1898–1930 near Point Barrow, Admiralty Bay (in Dease Inlet), Smith Bay, and Teshekpuk Lake (Appendix A). More recently, Snow Geese have been reported as uncommon, but regular, breeders on the Arctic Coastal Plain of northern Alaska (King 1970; Pitelka 1974; Derksen et al. 1981). During aerial surveys between Barrow and the Colville River in 1966, King (1970) recorded 19 broods of Snow Geese that were scattered on lakes within 2–3 miles of the coast. Prior to our surveys reported here, the only Snow Goose colony described in Alaska was the colony initiated in the 1970s at Howe Island, in the Sagavanirktok River Delta (Figure 1; Johnson 1996). This colony has grown from about 50 nests in 1971 to approximately 500 nests in the 1990s (Johnson and Herter 1989; Burgess et al. 1992*; Johnson 1996).

Our surveys provide the first specific information about the sizes and locations of Snow Goose colonies in the deltas of the Kukpowruk and Ikpihpuk rivers and provide information on nesting by small numbers of Snow Geese at 15 other locations. Museum collections and published records reveal that Snow Geese have nested near some of these locations for at least the past 100 years (Appendix A). The historical record is not detailed enough, however, to indicate whether other colonies existed on the Arctic Coastal Plain.

Records of occupation of the Kukpowruk River Delta colony by Snow Geese date to the early 1970s, when the Native village of Point Lay was reoccupied (Appendix A). Subsistence activities in the early 1970s included "egging" of Snow Goose nests on the island (Bill Tracey, Sr., Point Lay, personal communication). No museum specimens or other historical reports indicate that Snow Geese bred in the area before 1970, however. This lack of specimens may reflect the general lack of collecting by naturalists west of Barrow, rather than an absence of Snow Geese.

Historical records of nests and goslings indicated that Snow Geese nested in the region east of Barrow, primarily from Smith Bay (Ikpihpuk River Delta) to Teshekpuk Lake, since at least the 1920s (Appendix A). In 1982 and 1983, more than 40 Snow Goose

goslings were recorded during aerial surveys near the Ikpihpuk River Delta, prompting the investigator to note that this area was the "only known Snow Goose colony in Alaska, other than at Howe Island" (King, 1984*); however, the specific location of the colony remained unrecorded at that time.

Some of the other sites where we observed Snow Geese during our surveys also have a history of use for nesting by Snow Geese, based on collections and observations of eggs or broods (Appendix A). Examples include the Chipp River (Bailey 1948) and Garry Creek, east of Teshekpuk Lake (Derksen et al. 1979). The Teshekpuk region, however, is best known as a molting area for failed and nonbreeding geese, especially near Cape Halkett (King 1970; King and Hodges 1979); several Snow Geese from the Sagavanirktok River Delta have been recaptured near Teshekpuk Lake (Johnson 1991*).

We did not find Snow Geese nesting in the area between Wainwright and Barrow, where there are at least two historical nesting records (Appendix A). We may have failed to locate nests because survey coverage was limited in this subregion to a narrow (~5 km) coastal band in 1992–1994. However, it is unlikely that many nests occur in this subregion because the coast is exposed and often steep-banked and saltmarsh habitats are scarce.

Snow Geese may have been more abundant on the Arctic Coastal Plain before about 1930 than they are today. The historical record is not complete, however, and it does not reveal when or why a decline occurred. Most of the Snow Goose nests that we observed were located on deltaic and other coastal islands, similar to the habitats used by Snow Geese in the Sagavanirktok River Delta. A few were on small islands in tundra ponds, similar to those typically used by Brant (Stickney and Ritchie 1996). Because nesting habitat does not appear to be limiting for Snow Geese in any part of their range (Kerbes et al. 1983), the low numbers of nesting Snow Geese in northern Alaska may reflect some other limiting factor or combination of factors. Explanations may include predation and disturbance, low nesting productivity, limited habitats for brood-rearing, and isolation from major colonies, flyways, and staging areas.

Bailey et al. (1933) suggested that herds of reindeer (*Rangifer tarandus*) may have destroyed a Snow Goose colony near Barrow. Declines in Russian Snow Goose colonies also have been attributed to trampling by reindeer and to predation by foxes and collection of eggs for human consumption (Bousfield and Syroechkovskiy 1985). A decrease in numbers of nesting Snow Geese in northern Alaska also could have been due to consistently low nesting productivity caused by weather, predation, subsistence egg collecting, or limited availability of suitable brood-rearing habitat.

The establishment and growth of colonies might be constrained by the isolation of northern Alaska with

regard to their distance from other major colonies. For instance, it generally is accepted that Snow Geese nesting in northern Alaska are part of the Western Arctic Population of Lesser Snow Geese, which breeds primarily in the western Canadian Arctic (Subcommittee on White Geese 1992*; Johnson 1996). This determination is based in part on banding and resighting studies of Snow Geese from the Howe Island Colony in northern Alaska (Johnson 1996). However, some individuals of the Wrangel Island Population of Lesser Snow Geese, the large majority of which nest on Wrangel Island in Siberian Russia, may use the northern coast of Alaska during migration (Dzubin 1979), and it is possible that colonies described in this paper have been occupied by birds "dropping out" from this population during migration, as suggested for some of the more recently established colonies in Canada (e.g., McLaren and McLaren 1982; MacInnes and Kerbes 1987). If this has been the case, numbers of Snow Geese in this region of Alaska may reflect decreases in colony size of the Wrangel Island population since the 1970s (Subcommittee on White Geese 1992*).

BRANT

Early records, including egg collections, suggest that Brant were the most common nesting geese near Barrow in the early part of this century (Bailey et al. 1933; Bailey 1948). More recent surveys have confirmed the regular use of the region, particularly east of Barrow, primarily by molting and staging Brant. Hansen (1957*) first reported staging aggregations near Cape Halkett, northeast of Teshekpuk Lake. Estimates of the numbers of molting Brant in that area have ranged from ~9000 to 32 000 between 1970 and 1990 (King 1970; Derksen et al. 1979; King and Butler 1990*). In addition, research has established that Kasegaluk Lagoon regularly is used for staging by Brant from across northern Alaska (Lehnhausen and Quinlan 1981*; Johnson et al. 1993). Approximately 63 000 Brant were recorded there in August 1989 (Johnson 1993).

Few surveys of nesting Brant have been conducted on the western Arctic Coastal Plain. A reconnaissance survey from Cape Lisburne (west of Kasegaluk Lagoon) to the Colville River Delta in late June and early July 1960 recorded 400 nesting Brant, primarily between Barrow and the Colville River and within 40 km of the coast (Shepherd 1961*). Nest records exist for Peard Bay (Bailey 1948; Gill et al. 1985), Kasegaluk Lagoon (Divoky 1978), the Meade River and on lakes near Teshekpuk Lake (Derksen et al. 1979) (Appendix A).

We found Brant nesting in habitats similar to those recorded elsewhere in northern Alaska. Brant near the Meade River nested on raised mounds in flooded tundra areas within basin wetland complexes, and nests near Teshekpuk Lake generally were located near a lakeshore or on small islands in shal-

low or deep *Arctophila* wetlands (Derksen et al. 1979). Overall, habitats used by Brant for nesting also were similar to some habitats used by Brant on the central Arctic Coastal Plain (Stickney and Ritchie 1996): elevated mounds in moist or wet tundra, islets in basin wetland complexes, and deep-open lake wetlands. Few Brant in the study area were located on deltaic islands, although large colonies occur on the central Arctic Coastal Plain on the Colville, Kuparuk, and Sagavanirktok river deltas (Stickney and Ritchie 1996).

It is difficult to estimate how many Brant regularly nest in our study area and how their numbers compare with earlier estimates. Using the maximal number of nests identified at a location during any survey year as the colony size, we estimate 1100 pairs at 135 sites. Because annual variations in site occupancy occur and because movements among sites within larger "mega-colonies" or loose aggregations of nest sites undoubtedly occur this combined estimate may seem high. However, counts averaging 2800 adults recorded with broods (Table 2) during aerial surveys suggest similar or even higher estimates of breeding birds. Considering the fact that many Brant nest singly throughout the area, an annual breeding population of ~1100 pairs is not unreasonable. Counts at colonies for the rest of the Alaskan Arctic Coastal Plain total approximately 1800 nests (Stickney and Ritchie 1996; Johnson et al. 1996*), suggesting a total population of approximately 3000 breeding pairs of Brant on Alaska's Arctic Coastal Plain.

From our surveys, we can conclude that Snow Geese and Brant nest in a number of small colonies along the Arctic Coastal Plain of northern Alaska between the Colville River and Kasegaluk Lagoon. Although these colonies and their annual production represent relatively small portions of the estimated continental populations for these species (<0.1% of the Western Arctic Snow Goose population [Abraham and Jefferies 1997] and <5% of Pacific Brant breeding pair estimates [Sedinger et al. 1993]) they are valuable resources on a local and regional scale. Furthermore, as local (e.g., oilfield development, increasing human population) and continental environmental changes (e.g., warming trends, Snow Goose population increases) occur, it will be valuable to monitor their status and population trends. Our aerial surveys provide some important baseline information for management of these populations, but more site-specific data (e.g., nest fate, banding) will be required to understand what factors influence the abundance and distribution of Snow Geese and Brant in this region of northern Alaska.

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APPENDIX A. Historical records of Snow Goose and Brant breeding between the Colville River and Kasegaluk Lagoon, Alaska (1898–1991).

Subregion	Location	Species	Records
Harrison Bay	Colville River Delta	Snow Goose	Scattered pairs (Johnson and Herter 1989); 1–2 nests per year, 1993–1996 (Johnson et al. 1996*).
	Pitt Point	Brant	20 nests, 1952–1953 (D. H. Fiscus, unpublished field notes, UAF Museum ¹).
Smith Bay (includes Teshekpuk Lake)	Teshekpuk Lake	Snow Goose	Clutch of 5 eggs collected near “Tashipuk”, 17 June 1934 (WFVZ ²); nest near E. Long Lake, 1978 (Derksen et al. 1981), pair with one gosling, 1978 (Derksen et al. 1979); 3 and 10 young in region, 1982 and 1983 (King 1984*).
	Smith Bay/Ikpikpuk River	Snow Goose	Juvenile Snow Goose “60 miles east of Barrow” (FMNH #156365 ³); several broods (43 young), 15 km NW Teshekpuk, 1983 (King 1984*).
Barrow	Teshekpuk Lake	Brant	70–98 nests, Island Lake (Derksen et al. 1979).
	Dease Inlet/Admiralty Bay	Snow Goose	Clutches collected at Tangent Point by McIlhenny Expedition, 1898 (WFVZ); downy young from Chipp River delta, C. D. Brower, July 1928 (FMNH No. 160112); clutch, C. C. Brower, June 1942 (WFVZ).
	Barrow	Snow Goose	Nest located several miles inland from the Point (Brooks 1915 <i>in</i> Gabrielson and Lincoln 1959).
	Barrow	Brant	12 egg sets, 1923 (Bailey 1948).
	Cape Simpson	Brant	3 egg sets, 1924 (Bailey 1948).
Wainwright	Dease Inlet	Brant	8 egg sets at lagoons 50 mi SE Barrow, 1925 (Bailey 1948).
	Meade River	Brant	10 nests (Derksen et al. 1979).
	Peard Bay	Snow Goose	Several nests on an island and one clutch collected, Kugra (Kugrua) River, June 1898 (McIlhenny Expedition, WFVZ); nest, Franklin Bay, June 1900 (WFVZ; = Peard Bay).
	Peard Bay	Brant	Downy young with adults, spit at Peard Bay (Gill et al. 1985).
	Wainwright	Brant	3 egg set specimens, 1925 (Bailey 1948).
Kasegaluk Lagoon	Kasegaluk Lagoon	Snow Goose	2 pairs and 10 goslings, 8 km south of Kukpowruk River, Delta; pair, and 5 goslings, SW end of Kasegaluk Lagoon, July 1988 (Ritchie, ABR, unpublished notes); several small groups, including some goslings, near Avak Inlet, 1990 and 1991 (Johnson et al. 1993); 35–50 pairs with goslings, Kukpowruk River Delta, July 1990 and 1991 (Johnson et al. 1993).
	Pitmegea River	Snow Goose	10 adults and 7 goslings at mouth of Pitmegea River, July 1988 (Ritchie, unpublished data).
	Kasegaluk Lagoon	Brant	25 nests, Solovik Island; 25 nests, island between Akunik and Utokok Pass; and 6 nests, Icy Cape Spit, 1978 (Divoky 1978).
	Icy Cape	Brant	2 nests, 1980 (Lehnhausen and Quinlan 1981*).

¹UAF = University of Alaska, Fairbanks.²WFVZ = Western Foundation of Vertebrate Zoology.³FMNH = Field Museum of Natural History, Chicago.

Dispersal from and Fidelity to a Hibernaculum in a Northern Vermont Population of Common Map Turtles, *Graptemys geographica*

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Adult female Common Map Turtles, *Graptemys geographica*, ranging in carapace length from 160–260 mm were tracked with sonic equipment from November 1997 to November 1998. Seven of the 15 turtles tagged initially in 1997 returned to the same river hibernaculum in 1998. SCUBA observation demonstrated that hibernating females clustered together shell to shell in small and large groups often piled upon one another. They wintered fully exposed (unburied) but frequently positioned themselves against bottom debris (rocks, ledge outcrops, submerged logs). Ice covered the river from December through March. In April, when the ice had thawed, the animals emigrated to their summer home ranges. Range length for 6 females was 1.5 – 8.0 km along the river course. Total movements outside the hibernaculum ranged from 3.1 – 15.4 km. Some individuals moved downstream to Lake Champlain (2.7 km) and along the lakeshore as much as 2.2 km from the river's mouth. One individual moved 5.8 km upstream, then headed 9.5 km downstream to the lake before returning to the hibernaculum.

Key Words: Common Map Turtles, *Graptemys geographica*, hibernation, aggregation, movements, Vermont.

Riverine turtles experience considerable local and seasonal variation in their physical environment. Current velocity, water depth, and bottom characteristics can change dramatically within just a few meters of a river course. In addition, the river banks and bottom are continually being altered by current and fallen trees and other debris. In northern latitudes the formation of anchor ice can result in scouring of the substrate (Hynes 1970) and even freezing of turtles (Pluto and Bellis 1988). Animals inhabiting such mutable environments may react to seasonal fluctuations by altering their use of resources and migrating among habitats (Fretwell 1972).

Previous reports of turtle movements in lotic environments include those for Painted Turtles, *Chrysemys picta* (MacCulloch and Secoy 1983), Ouachita Map and False Map turtles, *Graptemys ouachitensis* and *G. pseudogeographica* (Vogt 1980), Smooth Softshells, *Apalone mutica* (Plummer and Shirer 1975), and Eastern Spiny Softshells, *Apalone spinifer spinifer* (Graham and Graham 1997). In addition, movements of Common Map Turtles, *Graptemys geographica*, have been reported for a lake (Gordon and MacCulloch 1980; Flaherty 1982) and a river (Pluto and Bellis 1988).

Map turtle hibernation behavior was described by Vogt (1980) for Wisconsin animals and more recently by Graham and Graham (1992) for Vermont turtles. Graham et al. (1997) presented additional observations on the same large wintering assemblage of Vermont map turtles. The purpose of our paper is to

describe seasonal movements and hibernaculum fidelity in the same riverine population of adult map turtles.

Methods

Field work was conducted from November 1997 to late November 1998 at the Lamoille River, Chittenden County, Vermont (44°36'15"N; 73°12'45"W) from the dam in Milton downstream to Lake Champlain. Detailed descriptions of this site were provided in previous studies (Graham and Graham 1992, 1997; Graham et al. 1997). Ice covered the river from mid-December 1997 until early April 1998 and reached a maximum thickness of 40 cm in January. An estimate of the hibernating population of adult map turtles, based on SCUBA mark-recapture data obtained from 5 November 1994 to 22 November 1998, was obtained using the Jolly-Seber method (Jolly 1965; Seber 1965). From this, the adult population size was estimated as 247 with a 95% confidence interval of 48–446. Since one of us (TEG) actually marked 349 individuals during that sampling interval, the adjusted 95% CI should be 349–446.

From 22–23 November 1997, 15 adult female *Graptemys geographica* ranging in carapace length (CL) from 160.9 – 259.5 mm (\bar{x} = 230.4, S.E. = 7.379, n = 15) were obtained from the hibernaculum site using SCUBA gear. They were then fitted with sonic tracking tags (Sonotronics model CT 82–2), each of which measured 16 × 64 mm, weighed 8 g,

possessed a battery life of 14 months, and a projected transmission range of 1000 m. The size and weight of these tags precluded their use on males, which are considerably smaller than females. During our study the actual effective range of these tags was 500 m. These tags produce unique aural codes that make identification of individual animals possible; e.g., tag 258 gives off 2 sound pulses, rest, 5 sound pulses, rest, 8 sound pulses, rest, and repeat. Following tag attachment, the animals were released at the hibernaculum site and their location was determined monthly through March 1998 and thereafter by boat on selected dates using a Sonotronics DH-4 directional hydrophone and a USR-96 tracking receiver. All turtle locations determined through 22 November 1998 were recorded on a base map and total annual movements and range lengths (Pluto and Bellis 1988) were measured from these plots. Total annual movement was taken as the sum of the distances moved between tracking trials, while range length was taken as the distance between the two most extreme locations for each animal.

Results

All tagged animals remained in the vicinity of their release location (the hibernaculum) at least through 21 March 1998 when the river was still covered by ice, water temperature was 0.1°C, and DO was 14.2 ppm. Values for water temperature (T_w) were obtained near the bottom (6 m). When we returned to the site on 26 April the ice was gone and all animals had left the hibernaculum (Table 1). On subsequent tracking trials we successfully located as few as one animal and as many as seven (Table 1). High water during the spring and early summer confounded our efforts to receive signals from many animals due to the fact that woodlands adjacent to the river course were flooded by at least a meter of water. We suspect that some animals moved into that setting and were undetectable with the hydrophone since trees, brush, and other debris can screen out or

absorb sonic signals. From Table 2, annual movement varied from 3.1 – 15.4 km among individuals and range length varied from 1.5 – 8.0 km.

Discussion

We feel that loss of sonic tags, rather than their failure, resulted in the recovery of only 7 of 15 sonic-tagged map turtles at the end of our study. Because we were unable to pick up signals from many animals once they left the hibernaculum, we feel that most of the first animals tagged (8, using monofilament fishing line) may have lost their tags in flooded woodlands and marshes away from the river course outside the range of our hydrophone. At the same time, 6 of 7 animals tagged using PVC pipe sleeves were found at the end of the study, suggesting that if we had attached all tags this way we would have recovered a much higher percentage of them.

As in our study, Pluto and Bellis (1988) found great individual variation among females in the length of river covered in their movements. They measured mean upstream movements ranging from 0.63 – 5.35 km (\bar{x} = 3.21) by gravid females in June and July and observed range lengths varying from 0 – 5.29 km (\bar{x} = 1.21). Gordon and MacCulloch (1980) noted extensive movement of female map turtles into bays of a Quebec lake where nesting occurred in May and June. The most one female moved during their study was 5–6 km (our estimate from their figure). In a study done in the same lake from May 1980 to February 1981, Flaherty (1982) found female map turtles traveled 3.22 – 19.5 km (\bar{x} = 12.5). Four of six tagged females moved to their hibernaculum between 22 August and 29 September. Three of them were later located under ice at this site in January and February; no depth or other hibernaculum characteristics were given.

From Table 1, it appears that departure from and return to the hibernaculum is controlled by water temperature, and occurs when water on the bottom

TABLE 1. Field data for adult female map turtles sonic-tracked in the Lamoille River and Lake Champlain, Vermont. Animals located at the hibernaculum are bracketed by asterisks (*).

Date	T_w (°C)	Animals located
22 November 1997	1.2	*15 tagged initially*
13 December	1.0	*All*
24 January 1998	0.1	*All*
28 February	0.2	*All*
21 March	0.1	*All*
26 April	12.1	267, 276, 357, 366
21 May	18.9	285, 348, 357, 366, 465
27 June	22.2	366
20 August	21.1	267, 276, 339, 348, 357, 375, 465
17 October	11.1	*267, 276, 339, 348, 447, 465*
22 November	2.0	*267, 276, 339, 348, 357, 447, 465*

TABLE 2. Annual movement and range length for six female map turtles sonic-tracked in the Lamoille River between 22 November 97 and 22 November 1998.

Animal number	Carapace length (mm)	Annual Range movement (m)	length (m)
267	214.8	3100	1500
276	186.1	6600	1900
348	256.9	5300	2050
357	243.5	9200	3850
366	160.9	8200	3600
465	259.5	15400	8050

reaches 11–12°C. Movement to the hibernaculum may be cued by decreasing water temperature, which may be the most critical factor stimulating hibernation in reptiles (Gregory 1982). Conversely, the seasonal emigration from the hibernaculum is probably related to the need to obtain adequate food when the ambient temperature rises and feeding rates increase (Mahmoud and Klicka 1979). Food availability in the deep waters of the hibernaculum may be a limiting factor since SCUBA observation did not reveal significant amounts of invertebrate prey there at any time. Thus, the shortage of food may cause the map turtles to move out to their summer home ranges, as was the case for a riverine population of this species in Pennsylvania (Pluto and Bellis 1988).

Our observations demonstrate that map turtles probably seek wintering sites with unique features, as we found only one hibernaculum in nearly 9.8 km of river course. This site was discovered in 1989 using SCUBA equipment (Graham and Graham 1992). We continued to search for additional hibernacula using SCUBA nearly every fall through 1996 as well as on numerous occasions during the present study (1997–1998). None of these efforts were successful. Unlike snapping turtles in Ontario, that changed hibernaculum type from year to year and utilized stream, lake shoreline, and lake mud hibernation sites (Brown and Brooks 1994), all of the map turtles we were able to sonic-track successfully (7 of 15) returned to the same hibernaculum used the previous year. Furthermore, the fact that several hundred adults use this same site every year (Graham et al. 1997) indicates that it is not chosen randomly and that its characteristics are probably unique, preferred, and recognized by animals migrating each fall. The depth of the site (6–7 m) is greater than any other place on the lower section of the river (from the Route 2 bridge 3.9 km down to the lake; bathymetry by J. Bonin, personal communication). Pluto and Bellis (1988) also found that *Graptemys* hibernating in Pennsylvania moved by early fall to the deep, slow-flowing section of the river.

The physical structure of our hibernation site includes a variety of bottom features such as exposed ledge, boulders of various sizes, and tree trunks, which probably afford security to wintering animals

since they congregated under or near them in most instances. We usually saw hibernating adults lying upon one another, or beside one another with shells touching. They appeared to select these microhibernacula in the deep and dark depression in the river bed (Graham and Graham) that allowed them tactile recognition of one another. A feature of the bottom of this depression is very slow (nil) current, which is probably reduced further when the animals lie shielded from it against objects on the bottom. Vogt (1980) reported that the map turtles *Graptemys geographica*, *G. pseudographica*, and *G. ouachitensis* overwinter communally by wedging between rocks behind wing dams in the sloughs and channels of the Mississippi River. Again, the tendency of map turtles to aggregate during hibernation indicates that they prefer hibernaculum features that are not widely available throughout their home range. We suggest that preferred sites must combine the following: (a) water deep enough to avoid freezing and scouring by ice, (b) sand or gravel substrate with negligible current, and (c) cover in the form of water-logged trees, exposed ledge outcrops, and scattered boulders. Snapping Turtles, *Chelydra serpentina*, also tend to congregate in winter in Ohio but their hibernation sites are usually shallower so that their long necks can reach the surface for air, are soft mud for burrowing, positioned to freeze over late and/or thaw early, and possessed of additional hiding cover such as brush, roots, an overhanging bank, or a Muskrat, *Ondatra zibethicus*, burrow (Meeks and Ultsch 1990). In Ontario, where winters are much more severe, Brown and Brooks (1994) found Snapping Turtles hibernating unburied in streams at depths of 0–1 m beneath thick ice cover. They felt that while shallow stream hibernacula afford access to higher oxygen levels, they are dangerous because if water level falls, turtles may freeze. In our much deeper hibernaculum the danger of turtles freezing due to water level drop was nonexistent.

We believe the physical structure of the habitat is not the only stimulus for congregation during hibernation in adult *Graptemys*. It is likely that there is a social component to this aggregative behavior that may similarly give rise to their propensity to aggregate for basking and nesting at other times of year.

Flaherty and Bider (1984) hypothesized that social function, in addition to habitat structure, was responsible for the distribution of *Graptemys geographica* on basking and nesting sites in southwestern Quebec. Whatever the proximate cause of this aggregative behavior, the annual autumnal assembly of map turtles is remarkably reminiscent of a jubilee, which is the unusual congregation of aquatic animals familiar to rural residents of the deep south (Carr 1994).

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Snowshoe Hare, *Lepus americanus*, Fecal Pellet Fluctuations in Western Montana

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Snowshoe Hare (*Lepus americanus*) fecal pellets counted from 1986 to 1998 on four transects in western Montana fluctuated in what appeared to be a low amplitude cycle, with a period of 7 years between peaks. Within transects, pellet densities differed 2.4- to 4.7-fold. Pellet densities were higher on the two transects placed in stands dominated by 80 to 90 year-old Lodgepole Pine (*Pinus contorta*), and lower on transects placed in stands dominated by older Lodgepole Pine and Douglas-fir (*Pseudotsuga menziesii*). The observed fluctuations occurred in fragmented habitat in the presence of many species of generalist predators.

Key Words: Snowshoe Hare, *Lepus americanus*, fecal pellets, population cycles, Montana.

Snowshoe Hare (*Lepus americanus*) populations at low latitudes are not known to exhibit the 8 to 11 year cycle typical of high latitudes, although no study of sufficient duration to detect cyclicity has yet been conducted (Keith 1990). Short-term studies of low-latitude hare populations in the west have found them to occur at low and apparently stable densities over the periods studied (Adams 1959; Dolbeer and Clark 1975; Koehler 1991). Naturally fragmented forests and the nearby presence of a suite of generalist predators in unsuitable hare habitat have been suggested as the factors preventing development of cyclic fluctuations (Howell 1923; Wolff 1981).

In western Montana, Snowshoe Hares are most noticeably common in Lodgepole Pine (*Pinus contorta*) forests, although they also occur in associated forest types (Koehler et al. 1979). Those forests are fragmented by montane topography (Romme and Knight 1982), natural fire regimes (Heinselman 1981), and land management practices (Lehmkuhl 1981), and are bordered by areas that support many species of generalist predators (Adelman 1979; Smith 1984). The objective of this study was to determine Snowshoe Hare fecal pellet densities in habitats typical of this area over the course of what would be one cyclic period.

Study Area and Methods

The study was conducted in the Garnet Mountains of western Montana (46° 50'N, 113° 22'W). I selected this site because it was within the area used by a radio-collared Canada Lynx (*Lynx canadensis*) in 1983 (Brainerd 1985 and personal communication). Because lynx are obligate predators of Snowshoe Hares (Keith 1963), I assumed that an area used by lynx would represent suitable hare habitat. Lodgepole Pine is the dominant tree on higher elevation sites,

with Subalpine Fir (*Abies lasiocarpa*) and Engelmann Spruce (*Picea engelmannii*) also occurring in the overstory. Douglas-fir (*Pseudotsuga menziesii*) is the dominant tree on lower elevation sites, with Lodgepole Pine also occurring in the overstory. The size of forest stands is constrained by changing slope, aspect, and elevation, and stands are smaller than the vegetation units illustrated in maps of high latitude hare habitat (Rusch et al. 1971) or observed by me in Alaska, but larger than the vegetation units depicted for other examples of low latitude hare habitat (Adams 1959; Rongstad and Tester 1971; Keith et al. 1993). I am aware of no quantitative analysis of habitat fragmentation for this study area, but closed canopy coniferous forest constituted 67% of the landscape in the adjacent and similarly managed Chamberlain Creek drainage before a recent logging program was implemented (M. G. Burcham and C. L. Marcum, University of Montana, unpublished data). Forest cover elsewhere in western Montana is also considered to be fragmented (Hart 1994).

To avoid bias in the location of sample sites, I established four Snowshoe Hare fecal pellet transects 1.6 km apart on section corners of the rectangular grid system used for the subdivision of public lands in Montana. Each transect consisted of 33 plots spaced 10 m apart, with each circular plot covering an area of 1 m². Plots on a transect were arranged in the shape of a cross, with a single central plot and four arms of eight plots each oriented toward the four cardinal points of the compass. Two transects were established and cleared of existing fecal pellets in 1985, and one each in 1986 and 1987. The first three transects were located in Lodgepole Pine-dominated stands (elevations 1800 to 1900 m), and the last in a Douglas-fir stand (1740 m). All stands in which transects were located were estimated to be of

pole size and 161 to 200 years old in 1940, when they were examined during the Western Montana Timber Survey (Hart and Lesica 1994), so all were greater than 200 years old when pellet counts began. However, increment boring of randomly selected trees indicated that the three lodgepole transects were dominated by trees much younger than that. Randomly selected trees on transects 1 and 3 were 80 to 90 years old, and trees on transect 2 were 95 to 105 years old. The markedly uneven-aged Douglas-fir stand in which transect 4 was located contained many trees 110 to 140 years old. The area has experienced some disturbance since the time of stand origin, primarily associated with harvest of building materials for the now-abandoned town of Garnet located nearby, and with spot burning during the 1910 fire year.

From the date of establishment until May 1998, fecal pellets were counted and cleared from each plot twice per year, once in late May or early June and again in late September or early October. Each year's spring count was combined with the previous year's fall count to form an annual count, from which annual pellet densities were calculated. Fecal pellet densities have been shown to be highly correlated with Snowshoe Hare population estimates derived from mark-recapture studies (Krebs et al. 1986), so fluctuations in pellet densities probably reflect real fluctuations in hare densities.

To verify the assumption that fecal pellets did not decompose between my visits to the plots, I established a decomposition enclosure 2 m northwest of the central plot of each transect in May 1996. I placed 10 freshly collected pellets in the center of each of the circular enclosures, which were 0.2 m in diameter and 0.1 m high, constructed of aluminum window screen and supported by wooden stakes. Those pellets could have been deposited by hares as long as seven months before I collected them, although I attempted to collect only those pellets that appeared to be fresh. Number and condition of pellets remaining in the decomposition enclosures were recorded in October 1996, May 1997, October 1997, and May 1998.

Results and Discussion

Three of 40 fecal pellets disappeared from within the decomposition enclosures during the first 12 months of exposure. However, no evidence of decomposition was seen among the 37 remaining pellets until 16 months after the trials began. I do not know how the three missing pellets disappeared from the enclosures, but the remaining pellets were displaced from their initial positions in the centers of the enclosures to the inside edges of the screens on their downhill sides. Pellet displacement was apparent only at the time of the spring counts, suggesting meltwater as the cause. I found no significant correlation between maximum snowpack recorded in March at

the nearest weather station (U.S. National Oceanic and Atmospheric Administration, Climatological Data, Montana, 1989-1998), which I chose as an index of spring snowmelt, and total pellets counted (Spearman's $r_s = -0.01$, $p = 0.99$) or pellets counted in spring only ($r_s = 0.06$, $p = 0.87$). If fluctuations in pellet density were caused merely by year-to-year variation in meltwater transport of pellets to local topographic depressions, a strong correlation with snowmelt would be expected. I do not know that meltwater was responsible for pellet displacement, but I assumed that whatever processes were responsible for movement of pellets in the enclosures also had similar net effects in all years of the study on pellets deposited on the annually cleared plots.

Pellet densities on transects 1 and 3 fluctuated in synchrony in what appeared to be a low amplitude cycle, with seven years between peaks (Figure 1). Pellet densities were also consistently higher on transects 1 and 3, and pellet fluctuations on those two transects more closely resembled the sine curve expected of cyclic hare populations (Bulmer 1974). Pellet densities on transects 2 and 4 did not fluctuate in synchrony with each other or with the two higher density transects. Within transects, pellet densities differed 2.4- to 4.7-fold.

The maximum pellet densities recorded in this study did not reach the extremely high densities typical of the cyclic peaks of high latitude populations (Keith and Windberg 1978; Krebs et al. 1995; T. N. Bailey, personal communication). Pellet densities recorded from transects 1 and 3 also did not decline to the very low densities typical of high latitude cyclic troughs. However, at least one high latitude fecal pellet time series (Poole 1994) declined in the final year of the study to an apparent cyclic low that was higher than the densities observed in this study.

Although differences in methods make comparisons difficult, peak annual pellet densities in these old stands were greater than the multi-year standing crop pellet densities Koehler (1991) found in stands greater than 80 years old, but lower than the densities in those of his stands less than 25 years old. Hare habitat in the Garnet Mountains would be considered suboptimal for a low-latitude site in the west based on old stand ages (Koehler and Brittell 1990; Koehler 1991), but Snowshoe Hare fecal pellets were deposited on all four transects during summer and winter throughout the study.

The fluctuations recorded during this study differ from descriptions of the classical hare cycle in having a short apparent period (7 years, rather than 8 to 11 years) and a low amplitude (2- to 4- fold difference between peaks and troughs, rather than greater than 13-fold). Reports of 7-year periods are not unusual. Before the population ecology of Snowshoe Hares began to be rigorously investigated, the period of their cycles at both low and high latitudes was popularly believed to be 7 years (Preble 1908;

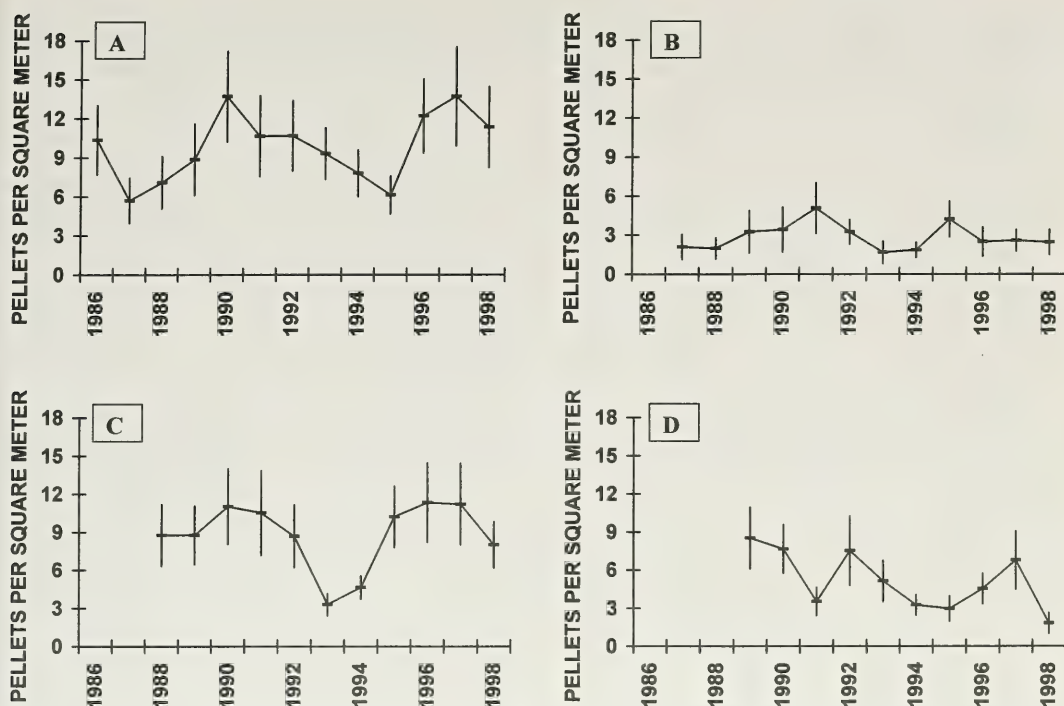


FIGURE 1. Mean (± 1 SE) Snowshoe Hare fecal pellet densities (pellets/m²) recorded from 1986 to 1998 on (A) transect 1, (B) transect 2, (C) transect 3, and (D) transect 4.

Hewitt 1921; Green et al. 1939), and modern investigators have reported peak-to-peak intervals of 7 years among periods of greater length in long time series of hare data (Marshall 1954; Keith 1963). The low amplitude of the observed fluctuations would be unusual for a cyclic population. Although there appears to be no north-south gradient in amplitude of hare cycles when evaluated across the entire range of the species (Keith 1963), the few studies conducted at low latitudes that appeared to reveal cycles (Green and Evans 1940; Grange 1949; Brooks 1955) showed low (3- to 17-fold) peak-to-trough differences. The low amplitude of the observed fluctuations is also similar to that reported from Anticosti Island, Quebec, where a cycle of low but unmeasured amplitude was attributed to the broader diets of Red Foxes (*Vulpes vulpes*) preying on the hares in the absence of Canada Lynx (Finerty 1980). Fluctuations of lower than normal amplitude and shorter than normal period are also typical of Fennoscandian microtine populations living at low latitudes in the presence of generalist predators (Hanski et al. 1991). The possibility of cyclicity at low latitudes in the west was considered and tentatively rejected by Chitty and Elton (1937), but the low amplitude fluctuations observed in this study probably would have escaped the notice of investigators analyzing questionnaire data, since a 6-fold

decline in central Alberta went generally unnoticed by local residents (Windberg and Keith 1978).

The resemblance of the pellet data to a sine curve demonstrates only that the data are consistent with the pattern expected of a cyclic population. Only two peaks and one trough are encompassed by this short time series. The important criterion of recurrence of the cyclic period (Davis 1957) cannot be evaluated with these data, so the possibility remains that they may represent random-type fluctuations (*sensu* Keith 1963), rather than a cycle. However, while these data do not unequivocally demonstrate the existence of cyclicity among low latitude hares, they certainly do not falsify it. I suggest that students of the Snowshoe Hare cycle consider the possibility that hares cycle in western Montana and perhaps elsewhere at low latitudes, even when they occupy fragmented habitats in the presence of many species of generalist predators.

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Breeding Success of Black-legged Kittiwakes, *Rissa tridactyla*, at a Colony in Labrador During a Period of Low Capelin, *Mallotus villosus*, Availability

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We monitored the breeding of Black-legged Kittiwakes, *Rissa tridactyla*, at a small colony at the Gannet Islands, Labrador, in 1996–1998, for comparison with the period 1981–1985. In the intervening years, capelin availability declined, coincident with major oceanographic changes in the Northwest Atlantic; capelin, *Mallotus villosus*, is the main prey of many breeding seabirds in this region. During 1996–1998, fewer kittiwake nests were built, fewer pairs that built nests laid eggs, and laying was late compared to 1981–1983. As in 1984 and 1985, kittiwakes raised few young at the Gannet Islands in 1996–1998. Concurrent studies showed that murres, *Uria* spp., also laid later in 1996–1998 than in 1981–1983, but their breeding success was little affected by the reduction in capelin availability. It appears that kittiwake breeding failure was caused by an inadequate early-season food supply. Our results suggest the importance of capelin to surface-feeding seabirds in this region, which do not have access to the alternative, benthic prey used by deep-diving seabirds.

Key Words: Black-legged Kittiwake, *Rissa tridactyla*, breeding success, capelin, *Mallotus villosus*, Labrador

Black-legged Kittiwakes, *Rissa tridactyla*, are colonial, cliff-nesting marine birds of boreal and Arctic waters. Their breeding success varies markedly in relation to the availability of key prey species – mainly pelagic, schooling fish – and so they are monitored widely at both Atlantic and Pacific colonies as indicators of marine feeding conditions (Harris and Wanless 1990; Hatch et al. 1993; Regehr and Montevecchi 1997). At colonies in the Northwest Atlantic, kittiwakes, like many other marine birds, are heavily dependent on capelin, *Mallotus villosus*, during the breeding season (Brown and Nettleship 1984).

Birkhead and Nettleship (1988) reported on the breeding success of Black-legged Kittiwakes at a small, recently-established colony at the Gannet Islands, Labrador (53°56'N, 56° 32'W), during 1981–1985. Between 1984 and 1996, capelin appears to have become much less available to marine birds at that colony (Bryant et al. 1999), possibly because capelin populations in Labrador shifted south (Frank et al. 1994; Carscadden and Nakashima 1997) in response to low water temperatures in the Northwest Atlantic (Drinkwater 1996). Cold-water events also delay the arrival of spawning capelin into nearshore waters, where they are accessible to marine birds (Montevecchi and Myers 1996; Nakashima 1996). Interestingly, Common Murres, *Uria aalge*, and Thick-billed Murres, *U. lomvia*, laid later in 1996–1998 than in 1981–1983 at the Gannet Islands, but their breeding success was little affected

by the reduction in capelin availability because these deep-diving seabirds were able to utilize alternative, benthic prey (mainly Daubed Shannies, *Lumpenus maculatus*, Bryant et al. 1999). However, benthic prey are not accessible to the surface-feeding kittiwakes. In this note, we report on the breeding of Black-legged Kittiwakes at the Gannet Islands from 1996–1998, during a period of low capelin availability, and make comparisons with observations from 1981–1985.

Study Area and Methods

Lying in the path of the Labrador current, the seabird colony at the Gannet Islands is part of a low-Arctic marine ecosystem (Nettleship and Evans 1985; Lock et al. 1994). Observations of Black-legged Kittiwakes were made in 1996–1998 on “GC4”, one of seven small islands comprising the Gannet Clusters, from the same blind used in 1981–1985 (see Birkhead and Nettleship 1987, 1995, for a description of the study site). All visible nests were watched and their contents recorded daily from early June (during the pre-laying period) until late August or early September (late in the nestling period). The following data were obtained: number of active nests (nests were considered active if vegetation was added in the current year), laying dates, number of eggs laid, number of chicks hatched, and number of chicks fledged. All observations from the 1980s refer to data reported in Birkhead and Nettleship (1988).

Results

Black-legged Kittiwakes were present at the colony in all three years when observations began in early June. From the observation blind, we were able to see 22 active nests in both 1996 and 1997, and 15 in 1998 (Table 1). From the same blind, observers were able to see 26 nests in 1981, 37 nests in 1982, and 42 nests in 1983 (Table 1). We do not know how many nests were visible from the blind in 1984 or 1985, but there were more nests in total at the Gannet Islands in those years than in any year between 1981 and 1983. In sum, it appears that there were many fewer active kittiwake nests in 1996–1998 than in 1981–1985.

Median laying dates for first eggs during our study ranged from 19 June in 1996 to 1 July in 1998 (Table 1). The modal clutch size was 2 eggs in 1996, but c. 80% of pairs that built nests in 1997 and 1998 failed to lay any eggs at all. In 1981–1983, median laying dates fell between 8–21 June, and modal clutch sizes were 2 eggs in each year (Table 1). Therefore, laying was late, and clutch sizes were small, in 1996–1998 compared to 1981–1983. There is no information available on clutch size or laying date for 1984 and 1985, because observers were not present at the colony during the laying period in either year. However, in both years, very few kittiwake nests contained eggs during checks made in early-to-mid July.

Breeding success of kittiwakes was low in 1996–1998, ranging between 0 and 0.8 fledglings per active nest (Table 2). The primary causes of the low success varied among the three years. In 1996, low hatching success was mainly responsible, whereas in 1997, few birds laid and none succeeded in hatching eggs. In 1998, as in 1997, low breeding success was due mainly to failure to lay eggs; the very few pairs that did lay experienced both high hatching and high fledging success (Table 2). In 1981–1983, kittiwakes at the Gannet Islands raised 0.9 – 1.1 fledglings per nest, higher than in 1996–1998 (Table 2). Breeding success was low in

1984 and 1985 as well, although it is not known whether this occurred because few pairs laid, or because many eggs were lost during incubation. Birkhead and Nettleship (1988) considered the former a more likely explanation.

Discussion

Black-legged Kittiwakes raised very few offspring at the Gannet Islands in 1996–1998. Fewer nests were built in these three years than in any year between 1981–1985, many pairs that built nests failed to lay eggs in 1997 and 1998, and timing of laying was late. Overall, breeding success in 1996–1998 was lower than in 1981–1983, but similar to 1984 and 1985. Our results suggest that kittiwakes failed because food availability was inadequate early in the season, as was probably true in 1984 and 1985 (Birkhead and Nettleship 1988); widespread failure to produce and hatch eggs has been reported at other colonies where kittiwakes experienced poor feeding conditions early in the season (Coulson and Thomas 1985; Murphy et al. 1991; Harris and Wanless 1997; Regehr and Montevecchi 1997). Concurrent studies at the Gannet Islands showed that Common Murres and Thick-billed Murres also laid later in 1996–1998 than in 1981–1983, again indicative of a poor early-season food supply. However, even though the diets that murres fed to their chicks included up to 75% less capelin in 1996–1998, neither breeding success nor chick growth rates were reduced (Bryant et al. 1999; Hipfner and Bryant 1999; R. Bryant unpublished). It appears that the surface-feeding kittiwakes were affected more strongly by adverse, early-season feeding conditions than were deep-diving seabirds that had access to alternative, benthic prey (see also Monaghan 1996).

What factors might have caused feeding conditions to be poor early in the season, resulting in delayed laying and extensive non-breeding by kittiwakes? There is no clear, obvious answer to this question. As at the Gannet Islands, many kittiwakes

TABLE 1. Laying dates and clutch sizes of Black-legged Kittiwakes at the Gannet Islands in 1981–1983 and 1996–1998. Modal clutch sizes are in bold.

Year	Number of active nests	Median laying date (first eggs)	Clutch size (%)				Mean clutch size ¹
			0	1	2	3	
1981	26	21 June	31	23	46	0	1.7
1982	37	18 June	16	16	62	5	1.9
1983	52 ²	8 June	19	8	64	10	2.0
1996	22	19 June	23	23	36	18	1.9
1997	22	25 June	77	18	5	0	1.2
1998	15	1 July	80	7	13	0	1.7

¹Excludes nests where no eggs were laid.

²Includes 10 nests on GC4 not visible from the blind

TABLE 2. Breeding success of Black-legged Kittiwakes at the Gannet Islands in 1981-1983 and 1996-1998.

Year	Number of active nests	Eggs		Chicks		Fledglings		
		Number	% hatching	Number	% fledging	Number	Per egg	Per nest
1981	26	30	87	26	92	24	0.80	0.92
1982	37	58	90	52	81	42	0.72	1.13
1983	52 ¹	85	72	61	77	47	0.55	0.90
1996	22	34	65	22	77	17	0.50	0.77
1997	22	6	0	0	—	0	0.00	0.000
1998	15	5	80	4	00	4	0.80	0.27

¹Includes 10 nests on GC4 not visible from the blind

also failed to breed at colonies 800 km to the south in Witless Bay, Newfoundland, in 1984 and 1985 (Birkhead and Nettleship 1988). These years were characterised by heavy spring ice conditions and low sea-surface temperatures, oceanographic conditions that persisted into the early 1990s in the Northwest Atlantic (Drinkwater 1996). However, in comparison to the cold, icy years between the mid 1980s and early 1990s, oceanographic conditions in 1996-1998 were relatively moderate. In general, both air and water temperatures for the Labrador Sea were similar to or warmer than the long-term average, and ice coverage was less extensive and of shorter duration than average (Drinkwater et al. 1997, 1998, 1999; Colbourne 1999). Moreover, kittiwakes bred relatively successfully in 1996-1998 at colonies in Witless Bay (J. W. Chardine unpublished). Therefore, in contrast to 1984 and 1985, breeding failure by Black-legged Kittiwakes at the Gannet Islands, in 1997 and 1998 particularly, was largely uncoupled from events occurring further south along the path of the Labrador current, and was unlikely to have been caused primarily by cold sea-surface temperatures or adverse spring ice conditions.

Fisheries surveys indicate that capelin populations in southern Labrador shifted south during the cold-water years of the mid 1980s to early 1990s (Carscadden and Nakashima 1997). The available data indicate that any declines in abundance of capelin in this region were not caused by overfishing (Narayanan et al. 1995). Although oceanographic conditions appeared to be more favourable in 1996-1998, surveys conducted during the latter part of the kittiwake breeding season detected almost no capelin in the southern Labrador Sea in 1996 (Anderson and Dalley 1997). Some juveniles were detected in 1997, and in 1998 their occurrence in the region was more extensive. Larval capelin were detected only in 1998, when they occurred along the coast of Labrador near the Gannet Islands (Dalley et al. 1999). However, in none of the three years of our study were local capelin distributions as extensive as in the mid 1980s (Dalley and Anderson 1997, 1998; Dalley et al. 1999; Anonymous 1999). Moreover, despite the warmer oceanographic conditions,

capelin in Newfoundland (members of the same stock as those in southern Labrador) continued to spawn late, and remained smaller than average (Anonymous 1999).

We suggest that the cold oceanographic conditions of the previous decade may have caused delayed laying and extensive non-breeding by Black-legged Kittiwakes at the Gannet Islands in 1996-1998, through lingering effects on the temporal and spatial distributions of capelin, and on their life-history characteristics. It would be worth continuing to monitor this small, isolated kittiwake population to see the effects that warmer oceanographic conditions, should they persist, will have on this marine ecosystem in the near future.

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New Records of Vascular Plants in the Yukon Territory II

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Nine native taxa including *Carex oligosperma*, *C. pauciflora*, *C. pellita*, *Chimaphila umbellata* ssp. *occidentalis*, *Draba densifolia*, *×Elylemus hirtiflorus*, *Eriophorum vaginatum* ssp. *spissum*, *Impatiens* ? *capensis*, and *Rhus radicans* are reported new to the known flora of the Yukon Territory. Eight introduced taxa are also reported as new to the known flora. Significant range extensions within the Territory are reported for 180 native and 17 introduced taxa. Comments are presented on three native taxa and two native taxa are deleted from the Territory.

Key Words: Vascular plants, Yukon Territory, flora, new records, range extensions, phytogeography.

Since the writing of *New Records of Vascular Plants in the Yukon Territory* (Cody et al. 1998), a considerable number of plant specimens have been submitted to Cody for identification and confirmation: Bruce Bennett, while working for the Canadian Wildlife Service in 1997 and 1998 collected many interesting species, particularly in the southeast of the Territory; in 1998 the Government of the Yukon, Department of Renewable Resources and the Yukon Forest Services, Indian and Northern Affairs Canada contracted ecological surveys of the area surrounded by the Alaska and Campbell Highways and the Canol Road; and the Government of Yukon, Department of Renewable Resources conducted surveys in wetlands south of Whitehorse and in a large area surrounding Aishihik Lake. In addition, Derek Johnson, Northern Forestry Centre, Forestry Canada, Edmonton, brought to the senior author's attention specimens that were collected in northern Yukon by S.C. Zoltai but were unfortunately not consulted during the writing of the *Flora of the Yukon Territory* (Cody 1996).

This paper serves to further update the Flora of the Yukon Territory (Cody 1996) along with other additional records recently published (Cody et al. 1998). The floristic information presented earlier and updated here is essential for biological research in the fields of agriculture, forestry, sustainable resource management, landscape planning, environmental assessment and wildlife management. With the additions of 9 native and 8 introduced species reported here the flora now includes 1151 species. The new native species are all rare (as defined by Douglas et al. 1981) in the Territory.

The taxa addressed in the body of this paper appear first in a synoptic list by Yukon status in alphabetical order. The taxa are then discussed in taxonomic order, as presented in the *Flora of the*

Yukon Territory with citation of specimens and other pertinent information. Common names follow Cody (1996) and Douglas et al. (1989, 1990, 1991, 1994). Most of the specimens which were sent to the senior author for identification and verification, have been incorporated in the vascular plant herbarium maintained by Agriculture and Agri-Food Canada at the Central Experimental Farm, Ottawa (DAO). Those not retained were photographed and the photographs have been preserved in DAO.

Synoptic List by Yukon Status

Native taxa new to the Yukon Territory (9)

Carex oligosperma

Carex pauciflora

Carex pellita (= *C. lanuginosa* of recent authors)

Chimaphila umbellata ssp. *occidentalis*

Draba densifolia

×Elylemus hirtiflorus (*Elymus hirtiflorus*, *×Agroelymus hirtiflorus*)

Eriophorum vaginatum ssp. *spissum* (*E. spissum*)

Impatiens capensis

Rhus radicans

Introduced taxa new to the Yukon Territory (8)

Asperugo procumbens

Caragana arborescens

Cerastium nutans

Elymus sibiricus (*E. pendulosus*)

Fagopyrum esculentum

Leymus angustus

Sonchus oleraceus

Trifolium cyathiferum

Range extensions of native taxa within the Yukon Territory (181)

Alopecurus aequalis

Alopecurus alpinus

Alyssum obovatum (*A. americanum*)

Anemone narcissiflora

Anemone parviflora

Anemone richardsonii

- Angelica lucida*
Antennaria densifolia
Antennaria howellii ssp. *canadensis*
Antennaria monocephala ssp. *monocephala*
Apocynum androsaemifolium
Arabis divaricarpa var. *dacotica*
Arabis glabra
Arabis holboellii var. *retrofracta*
Arctophila fulva
Arnica angustifolia ssp. *angustifolia*
Arnica chamissonis ssp. *chamissonis*
Arnica lessingii
Arnica lonchophylla
Artemisia frigida
Aster alpinus vierhapperi
Aster modestus
Astragalus australis
Astragalus umbellatus
Betula occidentalis
Botrychium ascendens
Botrychium spathulatum
Bromus pumpellianus var. *pumpellianus*
Calamagrostis purpurascens var. *purpurascens*
Calla palustris
Callitriche anceps
Caltha natans
Caltha palustris ssp. *arctica*
Calypso bulbosa
Campanula lasiocarpa
Campanula uniflora
Carex albo-nigra
Carex arcta
Carex atratiformis ssp. *raymondii*
Carex atrofusca
Carex aurea
Carex buxbaumii
Carex capillaris ssp. *capillaris*
Carex deflexa
Carex disperma
Carex glacialis
Carex gynocrates
Carex phaeocephala
Carex pyrenaica
Carex rostrata
Carex rotundata
Carex scirpoidea
Carex stylosa
Carex viridula
Carex williamsii
Cassiope tetragona ssp. *saximontana*
Cerastium arvense
Ceratophyllum demersum
Cicuta bulbifera
Cicuta maculata var. *angustifolia*
Circaea alpina ssp. *alpina*
Cornus stolonifera
Cryptogramma crispa var. *acrostichoides*
Cypripedium parviflorum var. *makasin* (= *C. calceolus* ssp. *parviflorum* of recent authors)
Cypripedium passerinum
Cystopteris montana
Descurainia incana
Douglasia arctica
Draba corymbosa
Drosera anglica
Drosera rotundifolia
Dryas crenulata
Dryas hookeriana
Dryas integrifolia ssp. *integrifolia*
Dryas integrifolia ssp. *sylvestris* var. *sylvatica*
Dryopteris carthusiana
Dryopteris fragrans
Elaeagnus commutata
Eleocharis acicularis
Elymus calderi
Elymus glaucus
Epilobium hornemannii
Erigeron grandiflorus ssp. *arcticus*
Eriophorum brachyantherum
Fragaria virginiana ssp. *glauc*
Gentiana prostrata
Geocaulon lividum
Geranium richardsonii
Geum macrophyllum ssp. *perincisum*
Glyceria grandis
Goodyera repens
Harrimanella stelleriana (*Cassiope stelleriana*)
Hieracium gracile
Juncus biglumis
Juncus bufonius
Juncus castaneus ssp. *leucochlamys*
Juncus drummondii
Juncus nodosus
Juncus triglumis ssp. *albescens*
Kalmia polifolia
Kobresia myosuroides
Lactuca biennis
Lathyrus ochroleucus
Lesquerella arctica ssp. *arctica*
Limosella aquatica
Loisleuria procumbens
Lupinus arcticus
Luzula arctica ssp. *arctica*
Lycopodium alpinum
Lycopodium clavatum var. *monostachyon*
Maianthemum canadense ssp. *interius*
Maianthemum trifolium
Mimulus guttatus
Minuartia elegans
Minuartia rubella
Minuartia yukonensis
Mitella pentandra
Muhlenbergia glomerata
Myosotis alpestris ssp. *asiatica*
Myrica gale
Myriophyllum sibiricum
Nuphar polysepalum
Oxytropis nigrescens ssp. *nigrescens*
Oxytropis sericea ssp. *spicata*
Parietaria pensylvanica
Parnassia fimbriata
Parrya nudicaulis
Phalaris arundinacea
Pinus contorta ssp. *latifolia*
Plantanthera hyperborea
Poa secunda ssp. *secunda*
Polemonium boreale
Polygonum caurianum
Polygonum lapathifolium
Polygonum viviparum

Potamogeton obtusifolius
Potamogeton praelongus
Potamogeton zosteriformis
Potentilla litoralis
Primula nutans
Pyrola asarifolia
Ranunculus flammula
Rhinanthus minor ssp. *borealis*
Rhodiola rosea ssp. *integrifolia*
Rorippa barbareifolia
Rumex salicifolius ssp. *triangulivalvis*
Sagina saginoides
Sagittaria cuneata
Salix pseudomonticola (S. *monticola*)
Salix pseudomyrsinites
Salix pyrifolia
Saxifraga aizoides
Saxifraga cernua
Saxifraga foliolosa
Saxifraga nelsoniana ssp. *pacifica*
Saxifraga razshivini (S. *davurica* ssp. *grandipetala*)
Scirpus microcarpus
Scirpus validus
Senecio congestus
Senecio kjellmanii
Sibbaldia procumbens
Silene involucrata
Sium suave
Sparganium minimum
Sparganium multipedunculatum
Subularia aquatica ssp. *americana*
Stellaria longifolia
Taraxacum ceratophorum
Thalictrum sparsiflorum ssp. *richardsonii*
Typha latifolia
Urtica dioica ssp. *gracilis*
Utricularia minor
Utricularia vulgaris ssp. *macrorrhiza*
Vaccinium ovalifolium
Vahlodea atropurpurea ssp. *latifolia*
Veratrum viride ssp. *eschscholtzii*
Vicia americana
Viola epipsela ssp. *repens*
Viola nephrophylla
Woodsia glabella
Zygadenus elegans

Range extensions of introduced taxa within the Yukon Territory (17)

Agropyron pectiforme
Artemisia biennis
Chenopodium album
Chenopodium denticulatum
Festuca rubra
Hordeum jubatum
Matricaria matricarioides
Matricaria perforata
Polygonum buxiforme
Polygonum fowleri
Senecio vulgaris
Sonchus arvensis ssp. *uliginosus*
Taraxacum officinale
Trifolium hybridum
Trifolium pratense

Veronica peregrina ssp. *xalapensis*
Vicia cracca

Comments on native taxa in the Yukon Territory (3)

Carex sychnocephala
Erysimum coerctatum
Parrya arctica

Deletions of native taxa from the Yukon Territory (2)

Draba paysonii
Zannichellia palustris

Annotated List by Family

LYCOPODIACEAE

Lycopodium alpinum L., Alpine Club-moss — YUKON: exposed rock on edge of alpine meadow, Beavercrow Ridge, 60°14'N 124°35'W, B. Bennett 98-321, 15 Aug. 1998 (DAO); slope on edge of dry ridge, Kotaneelee Range, 60°14'31"N 124°07'19"W, B. Bennett 98-086, 20 June 1998 (DAO).

The specimens cited above are an extension of the known range in the Yukon Territory to the southeast from a site west of longitude 129°W (Cody 1996) of about 325 kilometers.

Lycopodium clavatum L. var. *monostachyon* Hook. & Grev., Common Club-moss — YUKON: well drained sandy loam, burned area, 12 years old, black spruce, white spruce, *Salix*, near Porcupine River, 67°39'N 139°44'W, S.C. Zoltai s.n., 4 Aug. 1972 (CAFB, photo DAO).

In the Yukon Territory this taxon is rare north of 64°30'N where it was previously known only in the southern Richardson Mts. at 65°55'N and at Hanging Lake in the Barn Mts. at 68°23'N (Cody 1994).

OPHIOGLOSSACEAE

Botrychium ascendens W.H. Wagner — YUKON: Kluane Park, Alsek River, 22 km in from Alaska Highway, 60°39'N 137°49'W, P. Williston et al. PW98-507a, 22 Aug. 1998 (UBC, photo DAO)

The only other locality in the Yukon Territory of this rare species is in the vicinity of Dawson (Cody 1996) about 325 kilometers to the north.

Botrychium spathulatum W.H. Wagner — YUKON: mesic, 61°36'48"N 133°04'28"W, C.J. Keddy 98-39-9, 5 Aug. 1998 (DAO); alpine dwarf *Salix*, 61°29'35"N 132°49'02"W, 1803m, C.J. Keddy 98-34-6, 4 Aug. 1998 (DAO); 6 km SE of Mount Hogg, 61°17'28"N 132°12'25"W, 1721m, C.J. Keddy 98-48-7, 7 Aug. 1998 (DAO).

This species was previously known in the Yukon Territory from only a single collection from adjacent to the Canol Road (Cody 1996). The specimens cited above extend the known range in the Territory about 75 km to the southwest.

PTERIDACEAE

Cryptogramma crispa (L.) R.Br. var. *acrostichoides* (R.Br.) C.B. Clarke, Mountain-parsley — YUKON: in

crevices on rocky southeast-facing outcrop, Mount Haldane, 63°52'N 135°46'W, *R. Rosie 1851*, 15 July 1986 (DAO).

The specimen cited above is a northwest extension of the known range of this taxon of about 300 kilometers from a site adjacent to the Canol Road (Cody 1996).

Cystopteris montana (Lam.) Bernh., Mountain Bladder Fern — YUKON: White Spruce, low shrub, heath moss, Fishing Branch River, just above Bear Cave Mountain, 66°23'37"N 139°22'43"W, *J. Staniforth 97-23*, 28 Aug. 1997 (DAO); relatively moist side of mature White Spruce forest, Hills to the northeast of Rusty Springs camp, 66°28'N 140°00'W, *J. Staniforth 97-82*, 30 Aug. 1997 (DAO).

The specimens cited above are the northernmost yet reported in the Yukon Territory and extend the known distribution about 75 kilometers to the northwest of a site just north of latitude 66°N (Cody 1996).

ASPIDACEAE

Dryopteris carthusiana (Vill.) H.P. Fuchs, Spinulose Wood Fern — YUKON: shady spruce forest, Lower Beaver River, 60°01'30"N 124°31'40"W, *B. Bennett 97-258*, 10 June 1997 (DAO); *Picea glauca*, *Betula papyrifera* forest, same locality, *B. Bennett 97-170*, 10 June 1997; on slope above hot springs, Beaver River Hot Springs, 60°22'53"N 125°34'33"W, *B. Bennett 97-519*, 15 Aug. 1997 (DAO).

Cody and Britton (1989) and Cody (1996) knew this rare species in southeastern Yukon Territory only from the Coal River springs area. Cody et al. (1998) reported additional specimens to the east from adjacent to the La Biche River. The specimens cited above are from locations intermediate from those previously recorded.

Dryopteris fragrans (L.) Schott., Fragrant Cliff Fern — YUKON: dry rock outcrop, Beaver River, 60°09'09"N 124°55'16"W, *B. Bennett 97-516*, 19 Aug. 1997 (DAO).

Cody (1996) knew this species in southeastern Yukon Territory only as far east as near longitude 129°W. The specimen cited above extends the known range in the Territory eastward about 275 kilometers.

Woodsia glabella R.Br., Smooth Woodsia — YUKON: growing in crevice of rockface, Beaver River, 60°26'44"N 125°48'05"W, *B. Bennett 97-475*, 14 Aug. 1997 (DAO); dry rock outcrop, Beaver River Camp #1, 60°30'40"N 126°06'25"W, *B. Bennett 97-468*, 13 Aug. 1997 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as near longitude 127°20'W. The specimens cited above extend the known range about 100 kilometers to the northeast.

PINACEAE

Pinus contorta Dougl. ex Loud. ssp. *latifolia* (Engelm.) Critchfield, Lodgepole Pine — YUKON: roadside SE of river, crest of hill, La Biche Camp, 60°03'07"N 124°04'03"W, *B. Bennett 97-335*, 13 June 1997 (DAO).

Cody (1996) knew this species in the Yukon Territory only about as far east as longitude 127°15'W. The specimen cited above extends the known range about 180 kilometers to the east.

TYPHACEAE

Typha latifolia L., Common Cattail — YUKON: roadside, La Biche River, 60°07'42"N 124°02'21"W, *B. Bennett 98-226*, 14 June 1998 (DAO).

The specimen cited above from extreme southeastern Yukon Territory is from only the second known location in the Territory. It was previously known only from the vicinity of Mayo, about 775 km to the northwest and was considered rare by Douglas et al. (1981).

SPARGANIACEAE

Sparganium minimum (Hartm.) Fries, Small Bur-reed — YUKON: floating at edge of old gravel pit, La Biche River near N.W.T. border, 60°03'N 124°00'W, *B. Bennett 97-312*, 25 June 1997 (DAO).

Cody et al. (1998) extended the range of this rare species in the Yukon Territory to just east of the Nahanni Range Road and Watson Lake. The specimen cited above is an extension of the known range of about 250 kilometers to the extreme southeast of the Territory.

Sparganium multipedunculatum (Morong) Rydb. — YUKON: outflow of hot spring, Beaver River Hot Spring, 60°22'53"N 125°35'33"W, *B. Bennett 98-303*, 14 Aug. 1998 (B. Bennett Herbarium, photo DAO).

Cody et al. (1998) extended the known range of this species about 200 kilometers to the southeast from a site adjacent to the Campbell Highway. The location cited above is a further extension to the southeast of about 200 kilometers.

POTAMOGETONACEAE

Potamogeton obtusifolius Mertens & Koch — YUKON: wetland, depth 20 cm, 60°39'N 136°40'W, *J. Majiski 5023*, 23 July 1984 (DAO) (det. R.R. Haynes, 1995).

Cody (1996) knew this species in the Yukon Territory only from a site at Mt. Sheldon, adjacent to the Canol Road (Douglas et al. 1981).

Potamogeton praelongus Wulf., Long-stalked Pondweed — YUKON: "Cyclops Lake", 60°21'20"N 137°11'30"W, *R.D. Wickstrom 276.1*, 21 July 1974 (DAO); rooted in lake behind Iron Creek Lodge, Alaska Hwy. km. 958.5, 60°00'N 127°55'W, *W.J. Cody 32646*, 12 July 1983 (DAO); Gladstone Creek, Ruby Mountains, 61°23'N 138°04'W, *D. Leverton*, 1981 (DAO).

Douglas et al. (1981) knew this rare species in the Yukon Territory only from Burwash Landing and Mile 72 Dempster Highway. Cody (1996) mapped additional collections from Swan Lake (60°54'N 135°05'W), the Frances Lake area (61°11'N 129°07'W) and the Old Crow region in the north. *Potamogeton praelongus* is now known to be much more widespread in the Territory.

Potamogeton zosteriformis Fern., Flat-stemmed Pondweed — YUKON: emergent from pond behind Lee's Camp, Beaver River, *B. Bennett* 97-687, 60°11'57"N 125°09'42"W, 18 Aug. 1997 (DAO).

Cody (1994) reported this species as new to the flora of the Yukon Territory and more recently (Cody et al. 1998) extended the known range in the Territory north to the Old Crow Flats. The specimen cited above now extends the known range eastward about 650 kilometers.

Zannichellia palustris L., Horned Pondweed

This species was reported as new to the flora of the Yukon Territory by Douglas and Ruyle-Douglas (1978) and was included in *The Rare Plants of the Yukon* (Douglas et al. 1981) and *Flora of the Yukon Territory* (Cody 1996). The specimen upon which this was based (*R.D. Wickstrom* 362.1 *K-SCL*) was originally in the Canadian Wildlife Service Herbarium at Winnipeg which was broken up at the time of a move; specimens from the Yukon Territory and District of Mackenzie were sent to the Department of Agriculture Herbarium at Ottawa (DAO) but unfortunately were set aside because of other pressures. They have now been found and the specimen which had been identified as *Zannichellia palustris* has been re-examined and found not to be a flowering plant, but rather a somewhat similar looking species of an alga, *Nitella flexilis* (Cody 1998).

Zannichellia palustris should therefore be removed from the list of rare plants in the Yukon (Douglas et al. 1981) and the flora (Cody 1996).

ALISMATACEAE

Sagittaria cuneata L., Arrowhead — YUKON: wetland pond, Nordenskiöld River, 62°01'10"N 136°16'09"W, *M. Dennington* BAB-0431, 9 Aug. 1982 (DAO).

This is a rare species in the Yukon Territory (Douglas et al. 1981). The specimen cited above is an extension of the known range in the Territory of about 225 kilometers from sites in the vicinity of Johnson's Crossing (Cody 1996).

POACEAE

Agropyron pectiforme R. & S., Crested Wheat Grass — YUKON: disturbed area beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, *B. Bennett* 98-262, 14 June 1998 (DAO).

This introduced species is found occasionally in the Yukon Territory north to the vicinity of Mayo. The specimen cited above is an extension of the

known range in the Territory of about 240 kilometers east of the vicinity of Watson Lake (Cody 1996).

Alopecurus aequalis Sobol., Short-awned Foxtail — YUKON: Old Crow Flats, 68°1.375'N 140°33.971'W, *N.H. Hughes* NH-403, 27 July 1997 (DAO).

The specimen cited above is the northernmost yet found in the Yukon Territory. It is an extension of the known range of about 75 kilometers from a site adjacent to the Porcupine River near the Alaska border (Cody 1996).

Alopecurus alpinus J.E. Smith, Alpine Foxtail — YUKON: drainage catchment on till surface of valley bottom, Ogilvie Mountains, Tombstone Region, 64°21'42"N 138°35'59"W, *C. Grieser*, Plot #77, 8 July 1997, (DAO).

Cody (1996) knew this species only in widely separated localities in the mountains south of latitude 64°N and then disjunct to the Arctic coast. The specimen cited above is from about 174 kilometers west-northwest of a site northeast of Mayo.

Arctophila fulva (Trin.) Rupr., Pendantgrass — YUKON: riverbar with *Salix alaxensis*, sandy silt riverbank, Upper La Biche River, 60°13.963'N 124°13.968'W, *B. Bennett* 98-104, 17 June 1998 (DAO).

This species is widespread in the Yukon Territory but the nearest site to the location cited above is in the vicinity of Francis Lake (Cody 1996), about 300 kilometers to the northwest.

Bromus pumpellianus Scribn. var. *pumpellianus*, Smooth Brome — YUKON: subalpine in pockets in talus, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett* 98-269, 19 June 1998 (DAO).

Cody et al. (1998) extended the known range in southeastern Yukon Territory about 350 kilometers eastward from a site near the Canol Road. The specimen cited above is a further extension of the known range an additional 200 kilometers eastward.

Calamagrostis purpurascens R.Br. var. *purpurascens*, Purple Reedgrass — YUKON: area surrounding beaverpond, Larsen Hotsprings Lower Pool, 60°12'N 125°32'W, *B. Bennett* 97-536, 20 Aug. 1997 (DAO).

The specimen cited above is an extension of the known range eastward from a site mapped by Cody (1996) of about 125 kilometers.

× *Elylemus hirtiflorus* (A.S. Hitchc.) Barkworth (*Elymus hirtiflorus* A.S. Hitchc., × *Agroelymus hirtiflorus* (A.S. Hitchc.) Bowden) — YUKON: dry grassy slopes, vicinity of Cultus Bay, east side of Kluane Lake, 61°09'N 138°25'W, *R. Jacobson* 004, 27 June 1973 (DAO).

This hybrid of *Elymus innovatus* and *E. trachycaulus* was unfortunately not reported in the Flora of the Yukon Territory (Cody 1996).

Elymus calderi Barkworth, Calder's Wild Rye — YUKON: hillside, edge of *Alnus/Salix* thicket, Beaver River Camp #2, 60°28'08"N 125°52'01"W, B. Bennett 97-553, 14 Aug. 1997 (DAO); roadside, La Biche, 60°08'55"N 124°03'22"W, B. Bennett 95-248, 16 June 1995 (B. Bennett Herbarium, photo DAO).

Cody et al. (1998) extended the known range of this species eastward in the Yukon Territory to longitude 128°37'18"W. The specimens cited above are a further eastward extension of about 250 kilometers.

Elymus glaucus Buckl., Blue Wildrye — YUKON: area surrounding beaver pond, just downstream of "Hanging Garden", 60°20'51"N 125°39'21"W, B. Bennett 97-423, 14 Aug. 1997 (DAO); area surrounding beaver pond, Larsen Hotsprings Lower Pool, 60°12'N 125°32'W, B. Bennett 97-525, 20 Aug. 1997 (DAO).

This species, rare in the Yukon Territory (Douglas et al. 1981) was previously known only in the extreme southwest.

Elymus sibiricus L., (*E. pendulosus* Hodgson), Siberian Wild Rye — YUKON: river bar—sand gravel over clay, Beaver River—Larsen Creek area, 60°10'06"N 125°01'57"W, B. Bennett 95-275B, 18 June 1995 (DAO); on bank of river with *Lupinus*, Lower Beaver River, 60°02'00"N 124°31'40"W, B. Bennett 97-281, 10 June 1997 (DAO); on riverbars and banks, Beaver River, 60°18'35"N 125°20'58"W, B. Bennett 97-451, 17 Aug. 1997 (DAO).

Hodgson (1956) described *Elymus pendulosus* on the basis of a specimen collected at West shore Knik Arm—S Fish Creek, 61°04'N 149°08'W in Alaska. Bowden and Cody (1961) cited additional Alaskan specimens from Palmer, Eklutna, between Anchorage and Palmer, Talkeetna and Glen Highway when reporting *E. sibiricus* as new to the District of Mackenzie on the basis of a specimen from the vicinity of Fort Simpson and questioned if it was native or recently introduced there. On the basis of additional collections from adjacent to the Liard River, Cody (1963) concluded that it should be considered to be native in that area and also, Cody (1967) considered it to be native in northeastern British Columbia near Fort Nelson. Recent studies by the third author however now suggest that it is introduced in northwestern Canada and Alaska. Although already described and keyed in Cody (1996) this species is new to the flora of the Yukon Territory.

Festuca rubra L. sl., Red Fescue — YUKON: dry side of airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, B. Bennett 97-209, 27 June 1997 (DAO); meadow by road to upper gasline, Upper Gas Well, 60°07'25"N 124°06'02"W, B. Bennett 97-212, 23 June 1997 (DAO).

The specimens cited above are an extension of the known range in the Yukon Territory of about 200 kilometers east of the nearest location mapped by Cody (1996) at about longitude 127°44'W.

Glyceria grandis S.Wats., American Manna Grass — YUKON: wet ditch beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, B. Bennett 97-207, 27 June 1997 (DAO); in moist ditch beside airstrip, same locality, B. Bennett 98-458, 14 June 1998 (B. Bennett Herbarium, photo DAO).

Cody et al. (1998) extended the known range of this species into southeastern Yukon Territory to Frances Lake at 61°22'N 129°35'W. The specimen cited above extends the known range in the Territory about 325 kilometers to the southeast.

Hordeum jubatum L., Foxtail — YUKON: roadside, La Biche hill above gas plant, 60°07'25"N 124°06'02"W, B. Bennett 98-284, 14 June 1998 (DAO).

The specimen cited above is an extension of the known range in southeastern Yukon Territory (Cody 1996) of about 200 kilometers.

Leymus angustus (Trinius) Pilger — YUKON: roadside in sand near RCMP post on both sides of Klondike Hwy. near turnoff to Carcross, 60°10'N 134°42'W, B. Bennett et al. 98-461 (DAO); same locality, W.J. Cody 35633, 26 June 1999 (DAO).

This is an Asian species which has been cultivated at several Agriculture Stations in Canada and the United States. It has not been seen previously in the Yukon Territory or growing wild in any Canadian province. It may, however, now be presently used in seed mixtures used for ground cover protection. In southern Yukon Territory it can readily be separated from *Leymus innovatus* by its robust culms up to 1 m in height and long (up to 16 cm) straight spike.

Muhlenbergia glomerata (Willd.) Trin., Marsh Muhly — YUKON: sparse at edge of pool, Larsen Hotsprings Upper Pool, 60°12'N 125°32'W, B. Bennett 97-400, 20 Aug. 1997 (Bennett, DAO); gravel bar in river by hotsprings, Beaver River Hotsprings, 60°22'53"N 125°34'33"W, B. Bennett 97-541, 15 Aug. 1997 (DAO).

Douglas et al. (1981) considered this species as rare in the Yukon Territory on the basis of a collection from the vicinity of Watson Lake. The specimens cited above extend the known range in the Territory about 175 kilometers to the east.

Phalaris arundinacea L., Reed Canary Grass — YUKON: gravel bar in river by warm spring, Beaver River Hotsprings, 60°22'53"N 125°34'33"W, B. Bennett 97-524, 14 Aug. 1998 (DAO).

This species was considered rare in the Yukon Territory (Douglas et al. 1981). Cody (1994) extended the known range in the Territory north to Eagle Plains and Cody et al. (1998) further north to latitude 67°54'23.9"N. The specimen cited above is an

extension of the known range in the south of about 100 kilometers east of a site mapped by Cody (1996).

Poa secunda Presl ssp. *secunda*, Sandberg Bluegrass — YUKON: rocky cliff above the springs and terraces, Coal River springs, 60°09'N 127°25'W, *Scotter & Ahti* 24596, 16-19 July 1997 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 375 kilometers east of sites in the vicinity of Carcross.

Vahlodea atropurpurea (Wahlenb.) Fries ssp. *latifolia* (Hook.) A. E. Porsild, Mountain Hairgrass — YUKON: dwarf shrub dominated by *Luetkea pectinata*, Cassiar Mountains-Dorsey Range, 60°08'21"N 131°14'05"W, *C. Zoladeski* 98-21-4, 31 July 1998 (DAO); *Betula glandulosa*/*Sphagnum*, Cassiar Mountains-Dorsey Range, bottom of valley, 60°08'19"N 131°13'02"W, *C. Zoladeski* 98-23-1, 31 July 1998 (DAO); open forest in subalpine zone, Cassiar Mountains-Dorsey Range, 60°08'18"N 131°14'05"W, *C. Zoladeski* 98-20-4, 31 July 1998 (DAO); *Luetkea pectinata*/*Lycopodium alpinum* mesic meadow, upper end of small valley, Pelly Mountains, 1 km E of Mt. Hogg, 61°19'43"N 132°13'16"W, *C. Zoladeski* 98-55-4, 7 Aug. 1998 (DAO); *Luetkea pectinata*/*Phyllodoce empetriformis* meadow, upper end of small valley, Pelly Mountains, 1 km N of Mt. Hogg, 61°20'07"N 132°13'24"W, *C. Zoladeski* 98-52-5, 7 Aug. 1998 (DAO); open fir/ feathermoss forest, Pelly Mountains, 4 km SE of Rugged Peak, 61°22'48"N 131°33'07"W, *C. Zoladeski* 98-62-4, 9 Aug. 1998 (DAO); subalpine meadow with *Valeriana* and *Carex* amongst *Abies lasiocarpa* krumholtz, Beavercrow Ridge, 60°13'N 124°31'N, *B. Bennett* 98-468, 15 Aug. 1998 (DAO).

Cody et al. (1998) extended the known range of this species which was considered rare in the Yukon Territory by Douglas et al. (1981) - sub *Deschampsia atropurpurea* (Wahl.) Scheele var. *latifolia* (Hook.) Scrib., to the upper Hyland River area. It has not previously been reported from the area surrounded by the Alaska and Campbell Highways and the Canol Road or in the extreme southeast of the Yukon Territory. The Beavercrow collection cited above is an extension of the known range of about 260 kilometers southeast from the upper Hyland River site.

CYPERACEAE

Carex albo-nigra Mack., Two-toned Sedge — YUKON: alpine dwarf shrub type on flat ridge, Upper Lapie Lake, 61°36'20"N 132°18'59"W, *C. Zoladeski* 98-44-3, 6 Aug. 1998 (DAO).

This species is rare in the Yukon Territory (Douglas et al. 1981). The location cited above is intermediate between sites adjacent to the Alaska

Highway and sites to the northeast about latitude 62°30'N.

Carex arcta Boott, Northern Clustered Sedge — YUKON: emergent from put in lake, Beaver River, Moose Lake, 60°30'10"N 126°06'23"W, *B. Bennett* 97-404, 13 Aug. 1997 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The nearest known site to that cited above is from the vicinity of Francis Lake (Cody 1996) about 200 kilometers to the northwest.

Carex atratiformis Britt. ssp. *raymondii* (Calder) A. E. Porsild, Black Sedge — YUKON: riverbank, Beaver River Camp #1, 60°30'40"N 126°06'26"W, *B. Bennett* 97-365, 13 Aug. 1997 (DAO).

This species occurs in the Yukon Territory north to about latitude 64°N (Cody 1996). The specimen cited above is an extension of the known range in the Territory of about 200 kilometers to the southeast from the vicinity of Francis Lake.

Carex atrofusca Schk., Dark-brown Sedge — YUKON: headwaters of the Bonnet Plume River, *N. Hughes* s.n. (no date) (DAO).

This circumboreal species was not considered rare in the Yukon Territory by Douglas et al. (1981) because of its widespread occurrence. The specimen cited above is, however, an extension of the known range in the Territory of about 350 kilometers east of sites adjacent to the Dempster Highway (Cody 1996).

Carex aurea Nutt., Golden Sedge — YUKON: permafrost free mud, Old Crow Flats, 67°57.99'N 139°39.409'W, *N. Hughes* NH-417D, 28 July 1997 (DAO).

The specimen cited above is the northernmost yet found in the Yukon Territory. It is a northward extension of the known range of about 375 kilometers from a site adjacent to the Dempster Highway (Cody 1996).

Carex buxbaumii Wahlenb., Buxbaum's Sedge — YUKON: *Salix glauca*/*S. planifolia*, *Betula occidentalis* hummocks, Nisutlin River Delta, Colwell Bay, 60°14'12"N 132°33'17"W, *B. Bennett* 98-182, 29 July 1998 (DAO).

This is a widespread circumpolar species which is uncommon in the Yukon Territory north to about latitude 62°N (Cody 1996).

Carex capillaris L. ssp. *capillaris*, Hairlike Sedge — YUKON: Hyland River, 61°10'N 128°18'W, *Rosie & Mueller* 111-1-97, 27 June 1994 (DAO); dry scree below outcrop, Beaver River, 60°30'40"N 126°06'26"W, *B. Bennett* 97-417, 13 Aug. 1997 (DAO); steep scree slope, old burn, growing in crevice of rock face, Beaver River, 60°26'44"N 125°48'05"W, *B. Bennett* 97-456, 14 Aug. 1997 (DAO).

The easternmost locality known to Cody (1996) was in the vicinity of Frances Lake. The locations cited above extend the known range in the Territory about 220 kilometers to the southeast.

Carex deflexa Hornem., Bent Sedge — YUKON: open *Picea glauca*/*Populus balsamifera* forest on side of Mt. Martin in forest gap at base of stump, 60°07'25"N 124°26'02"W, B. Bennett 97-241, 20 June 1997 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 250 kilometers east from the vicinity of Watson Lake.

Carex disperma Dewey, Soft-leaved Sedge — YUKON: across river in marshy *Alnus incana*, *Salix* swamp, Beaver River Camp #4, B. Bennett 97-443 and 97-449, 17 Aug. 1997 (DAO); nutrient poor *Picea glauca* forest, La Biche River, crest of hill east of bridge, 60°03'13"N 123°59'57"W, B. Bennett 95-199, 13 June 1995 (DAO).

Cody et al. (1998) extended the known range of this species in the Yukon Territory eastward to about longitude 125°W. The specimens cited above extend the known range eastward an additional 60 kilometers.

Carex glacialis Mack., Glacier Sedge — YUKON: *Dryas* dominated shrub meadow, Rancheria River up slope on north side of Alaska Hwy., 60°05'23"N 130°35'52"W, C.J. Keddy 98-19-3, 30 July 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 225 kilometers southwest of a site reported by Porsild (1951) west of Mile 118 Canol Road at the Rose-Lapie River Pass.

Carex gynocrates Wormskj., Yellow Bog Sedge — YUKON: open Black Spruce-low shrub tundra, upper Fishing Branch River, 66°15'00"N 139°36'08"W, J. Staniforth 97-3, 28 Aug. 1997 (DAO).

With the exception of a single collection from adjacent to the Porcupine River all the collections known to Cody (1996) were from south of latitude 64°N. The collection cited above is from an intermediate site about 150 kilometers south of the Porcupine River.

Carex oligosperma Michx. — YUKON: Ethel Lake, off Rt. 3, 63°20'N 135°23'W, M.G. Duman 70-512, 11 July 1970 (DM, MICH, Xerox DAO).

Anton Reznicek kindly provided a photocopy of a specimen in the University of Michigan Herbarium (MICH) of this species which is new to the flora of the Yukon Territory. It should be added to the list of rare plants of the Territory (Douglas et al. 1981).

Carex pauciflora Lightfoot, Few-flowered Sedge — YUKON: habitat wet, south end of Lake Kluane, J.P. Anderson 9353, 22 July 1944 (ISC acc. no. 263530).

The specimen cited above was identified by Anderson as *C. microglochis* Wahlenb. but was later revised to *C. pauciflora* by Hultén (undated and in pencil) and was subsequently annotated as *C. pauciflora* by Stanley Welsh in 1969 and T. S. Cochrane in 1990. The map in Hultén (1968), sweeps across the southwest corner of the Yukon Territory, but there is no dot in that area and Welsh (1974) also did not include that area in his flora. Douglas (1994) did record it as occurring in the Yukon but without any reference. It should now be added to the list of rare plants in the Yukon Territory (Douglas et al. 1981). The two species can be separated as follows:

- A. Perigynia 6-7 mm long, without nerves; rachilla not exerted from the perigynium; culms trigonous, scabrous, aphyllipodic *C. pauciflora*
- A. Perigynia 4-5.5 mm long, with few nerves; rachilla conspicuously exerted from the perigynium; culms rounded, smooth, phyllipodic *C. microglochis*

Carex pellita Willd. (= *C. lanuginosa* of recent authors) — YUKON: Yukon River below Rink Rapids, 62°21'N 136°27'W, M.G. Duman 70-592, 15 July 1970 (MICH, Photocopy DAO).

Anton Reznicek kindly provided a photocopy of a specimen in the University of Michigan Herbarium (MICH) of this species which is new to the flora of the Yukon Territory. It should be added to the list of rare plants of the Territory (Douglas et al. 1981). This specimen was originally determined by Duman as *C. lanuginosa* but that name is correctly treated as a synonym of *C. lasiocarpa* Ehrh., the plants previously referred to it being correctly called *C. pellita* Willd. (McClintock and Waterway 1994).

Carex phaeocephala Piper, Dunhead Sedge — YUKON: pond edge, sedge meadow to dry lake bottom, Buffalo Lake, 61°25'22"N 137°01'44"W, Staniforth & Rosie 98-74, 25 Aug. 1998 (DAO).

This species which was considered rare in the Yukon Territory (Douglas et al. 1981) was known to Cody (1996) only from Kluane National Park and adjacent to the Haines Highway near the British Columbia border. The specimen cited above is an extension of the known range in the Territory of about 120 kilometers to the northeast.

Carex pyrenaica Wahlenb., Pyrenean Sedge — YUKON: slightly raised, drumlinoid till surface, Ogilvie Mountains, Tombstone Region, 64°25'36"N 138°27'31"W, S. Willsrud, Plot 93, 19 July 1997 (DAO); undulating to terraced bedrock benches, Ogilvie Mountains, Tombstone Region, 64°21'48"N 138°34'30"W, G. Grieser, Plot 72, 8 July 1997 (DAO); moist draw just below alpine ridge, *Abies lasiocarpa* krummholtz with *Kalmia* and *Spiraea*, Beavercrow Ridge, 60°13'N 124°32'W, Bennett et al. 98-488, 15 Aug. 1998 (B. Bennett Herbarium, photo DAO).

Specimens cited above are an extension of the range in the Yukon Territory mapped by Cody



FIGURE 1. *Carex pauciflora* (Drawn by Valerie Fulford).

(1996). This species was, however, reported by Kojima and Brooke (1985) from the Tombstone Range, but unfortunately missed by Cody. In the southeast, the Beavercrow Ridge specimen is an extension of the known range eastward of about 220 kilometers from sites reported by Cody et al. (1998).

Carex rostrata Stokes — YUKON: Liard Plateau, 60°06'N 128°30'W, *G. Brunner* 179-3-1, 23 July 1994 (DAO); Upper Coal River, 61°12'N 127°17'W, *C. Zoladeski* 341-3-2 and 340-2-8, 22 July 1994 (DAO).

Cody et al. (1994) reported this species which was then only known in the Yukon Territory from two



FIGURE 2. *Carex pellita* (Drawn by Marcel Jomphe).

widely separated areas (67°24'N 138°17'W and 63°51'N 138°02'W) and suggested that it should be included in the list of rare plants of the Territory (Douglas et al. 1981). The specimens cited above extend the known range in the Territory about 70 kilometers to the southeast.

Carex rotundata Wahl. — YUKON: Mackenzie Mts., headwaters of the Bonnet Plume River, *J. Meikle s.n.* (no date) (DAO); tall shrub muskeg, Finlayson Lake, 61°41'27"N 130°42'12"W, *J. Grods* 98-4-1, 9 Aug. 1998 (DAO); Mt. Hogg, 61°18'09"N, 132°13'53"W, *J. Grods* 98-54-2, 7 Aug. 1998 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981) but Cody (1996) demonstrated that it was widespread, particularly in the north. The first specimen cited above, which is from near the District of Mackenzie border, is an eastward extension of the known range in the Territory of about 350 kilometers from the Dempster Highway and a northward extension from near the Campbell Highway of about 250 kilometers. The second and third specimens are an extension of the known range southsoutheast from a site adjacent to

the Pelly River just west of longitude 133°W of about 125 kilometers.

Carex scirpoidea Michx., Single-spike Sedge — YUKON: alpine tundra: *Dryas-Salix reticulata*/moss, about 10 km N of Camp Ground on Nahanni Range Road, 61°23.38'N 128°22.51'W, *C. Zoladeski s.n.*, 12 Aug. 1995 (DAO); Hyland River, 61°22'N 128°20'W, *G. Brunner 125-37-5*, 26 July 1994 (DAO); on moist rock bench, Beaver River Hanging Gardens, 60°20'15"N 125°39'21"W, *B. Bennett 97-394*, 14 Aug. 1997 (DAO).

The specimens cited above extend the known range of this species about 250 kilometers to the southeast from a location mapped by Cody (1996) at approximately 62°N 129°W.

Carex stylosa C.A. Mey., Long-styled Sedge — YUKON: Site 1, 60°23'N 139°07'W, *Hoefs & Smitts 93-37*, 8 July 1993 (DAO).

This species, which was considered rare in the Yukon Territory (Douglas et al. 1981), was known to Cody (1996) only as far north as the vicinity of Dawson. The specimen cited above is an extension of the known range in the Territory north to the Arctic Coast. In Alaska, however, it is known to occur north of the Arctic Circle.

Carex sychnocephala Carey — YUKON: palustrine system, pond west of Horseshoe Slough, 63°26'N 135°07'W, *V. Loewen*, 14 Aug. 1988 (DAO).

This specimen, which is the northernmost yet collected in the Yukon Territory, and was reported by Cody (1994), was incorrectly plotted south of Whitehorse in the Flora of the Yukon (Cody 1996).

Carex viridula Michx., Green Sedge — YUKON: graminoid/sedge meadows at edge of lake to mud flats, south end of Stevens Lake, 61°41'40"N 137°30'12"W, *Staniforth & Rosie 98-183*, 28 Aug. 1998 (DAO); graminoid/forb dry slope, Tahgah River, 61°35'N 137°30'W, *Staniforth & Rosie 98-164*, 27 Aug. 1998 (DAO).

This species is rare in the Yukon Territory (Douglas 1981). The nearest sites to the above listed specimens are adjacent to the Alaska Highway about 100 kilometers to the east.

Carex williamsii Britt. — YUKON: open spruce forest/feathermoss, Rancheria Valley, 60°09'03"N 131°02'46"W, *J. Grods 98-27-5*, 1 Aug. 1998 (DAO).

This is a rare species in the Yukon Territory (Douglas et al. 1981). The nearest known site to that listed above is north of Aishihik Lake, about 400 kilometers to the northwest.

Eleocharis acicularis (L.) R. & S., Needle Spike-rush — YUKON: margin of small pond, 65°47'N 135°06'W, *S.C. Zoltai s.n.*, 10 July 1972 (CAFB, photo DAO).

Cody et al. (1998) reported a new locality in the

Old Crow Flats just north of 68°N latitude. The specimen cited above is from a site about 165 km northeast of the nearest location at Mile 84 on the Dempster Highway.

Eriophorum brachyantherum Trautv., Short-anthered Cotton-grass — YUKON: old roadbed, La Biche River, 60°03'41"N 124°01'25"W, *B. Bennett 97-197*, 16 June 1997 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 250 kilometers eastward from a site southeast of Watson Lake.

Eriophorum vaginatum L. ssp. *spissum* (Fern.) Hultén (*E. spissum* Fern.), Tussock Cottongrass — YUKON: moist west-facing slope, 33 miles on 60 Mile Road from West Dawson, approx. 64°13'N 140°21'W, *Calder & Billard 3350*, 26 June 1949 (DAO).

This specimen was plotted as ssp. *vaginatum* by Cody (1996) but was revised to ssp. *spissum* by D. E. Wujek in 1991 for the Flora North America project. Hultén (1968) knew this subspecies essentially near the coast in western and northern Alaska but also plotted three sites in eastern central Alaska which are west of the site reported above. It should be added to the list of rare taxa in the Yukon Territory (Douglas et al. 1981).

Kobresia myosuroides (Vill.) Fiori, Bellard's Kobresia — YUKON: moist draw, subalpine, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett 98-547*, 19 June 1998 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 500 kilometers east of sites adjacent to the Canol Road to the extreme southeast of the Territory.

Scirpus microcarpus Presl, Small-flowered Bulrush — YUKON: in outflow of hot spring, Beaver River Hot Springs, 60°22'53"N 125°34'33"W, *B. Bennett 98-302*, 14 Aug. 1998 (DAO); riverbank, Beaver River, 60°22'41"N 125°30'53"W, *B. Bennett 98-602*, 14 Aug. 1998 (DAO).

Cody (1994) reported the first known occurrence of this species in the Yukon Territory on the basis of a collection near the junction of the Stewart and Yukon rivers. A second collection from the La Biche River area was reported by Cody et al. (1998). The third and fourth collections of this species in the Territory, from about 90 kilometers west of the second collection are reported above.

Scirpus validus Vahl, Soft-stemmed Bulrush — YUKON: in shallow water, Campbell Highway, 22 km W of Coffee Lake, 61°54'50"N 132°27'26"W, *C. Zoladeski 98-67-2*, 10 Aug. 1998 (DAO); sedge meadow at lake edge, Buffalo Lake,

61°25'22"N 137°01'14"W, *Staniforth & Rosie* 98-77, 25 Aug. 1998 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The first specimen cited above is an extension of the known range of about 60 kilometers southeast of a site adjacent to the Pelly River and the second cited above is an extension of the known range in the west of about 130 kilometers northwest of a site near the south end of Lake Laberge.

ARACEAE

Calla palustris L., Water-arum — YUKON: in 6 inches of water near Wind River, 65°48'N 135°12'W, *S.C. Zoltai s.n.*, 7 July 1972 (CAFB, photo DAO).

Cody et al. (1998) extended the known range of this species in the Yukon Territory about 750 kilometers southeast from the vicinity of Mayo. The specimen cited above is from an area intermediate between Faro and the Porcupine River region.

JUNCACEAE

Juncus biglumis L., Two-flowered Rush — YUKON: moist draw just below alpine ridge, Beavercrow Ridge, 60°13'N 124°32'W, *B. Bennett* 98-491, 15 Aug. 1998 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 500 kilometers southeast of a site mapped by Cody (1996) adjacent to the Canol Road.

Juncus bufonius L., Toad Rush — YUKON: wet ditch beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, *B. Bennett* 97-155, 27 June 1997 (DAO).

The specimen cited above extends the known range in the Yukon Territory eastward about 280 kilometers from a site northwest of Watson Lake.

Juncus castaneus Smith ssp. *leucochlamys* (Zinz.) Hultén, Chestnut Rush — YUKON: river floodplain, grassy meadow at edge of old oxbow slough, North Fork of the Fishing Branch River, 66°33'08"N 139°17'48"W, *J. Staniforth* 97-42, 29 Aug. 1997 (DAO); same locality, *J. Staniforth* 97-52 (DAO); area surrounding beaver pool, Larsen Hotsprings Lower Pool, 60°12'N 125°32'W, *B. Bennett* 97-466, 20 Aug. 1997 (DAO).

Cody (1996) knew this subspecies in the Yukon Territory only as far north as 65°11'N and as far east as 60°00'N 127°52'W. The specimens cited above extend the known range in the Territory about 165 kilometers to the north and 125 kilometers to the east.

Juncus drummondii E. Meyer, Drummond's Rush — YUKON: moist subalpine meadow, Kotaneelee Range, 60°14'44"N 124°08'03"W, *B. Bennett* 98-044, 21 June 1998 (DAO); edge of alpine lake, Beavercrow Ridge, 60°13'N 124°35'W, *B. Bennett* 98-324, 14 Aug. 1998 (DAO).

Cody (1996) mapped a collection by S. M. Lamont collected in the La Biche Mountains near Dendale Lake [±60°47'N 124°52'W]. The specimens cited above extend the known range about 100 kilometers southward to the extreme southeast of the Yukon Territory.

Juncus nodosus L., Tuberous Rush — YUKON: in mud at warm spring, Frances Lake, 61°34'N 129°26'W, *R. Rosie* 1958, 19 July 1997 (DAO); outflow of hot spring, only place seen, Beaver River Hotsprings, 60°22'53"N 125°34'33"W, *B. Bennett* 98-296, 14 Aug. 1998 (DAO).

Cody (1996) knew this rare plant in the Yukon Territory only from the vicinity of Needlerock Creek and two localities in the extreme south between longitudes 127°21.5'W and 129°10'W.

Juncus triglumis L. ssp. *albescens* (Lange) Hultén, Whitish Rush — YUKON: moist draw just below alpine ridge, Beavercrow Ridge, 60°13'N 124°32'W, *B. Bennett* 98-492, 15 Aug. 1998 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 275 kilometers to the southeast from a site adjacent to Francis Lake.

Luzula arctica Blytt ssp. *arctica*, Arctic Woodrush — YUKON: slope on edge of dry ridge, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett* 98-255, 20 June 1998 (DAO).

This species is widely known in the western half of the Yukon Territory (Cody 1996). The specimen cited above however is an extension of the known range in the Territory of about 500 kilometers to the southeast from a site adjacent to the Canol Road near Ross River.

LILLACEAE

Maianthemum canadense Desf. ssp. *interius* (Fern.) A. & D. Löve, Wild Lily-of-the-Valley — YUKON: meadows surrounding hot spring, Beaver River Hotsprings, 60°22'53"N 125°34'53"W, *B. Bennett* 98-338, 14 Aug. 1998 (DAO).

Cody et al. (1998) reported this species new to the Yukon Territory on the basis of specimens collected adjacent to the Upper Gaswell, La Biche River and lower Beaver River areas. The specimen cited above is an extension of the known range of about 50 kilometers up the Beaver River.

Maianthemum trifolium (L.) Sloboda, Three-leaved Solomon's Seal — YUKON: wet *Sphagnum* area, 65°45'N 133°18'W, *S.C. Zoltai s.n.*, 14 July 1972 (CAFB, photo DAO).

This species, which was considered rare in the Yukon Territory by Douglas et al. (1981) was previously known only from the southeast and a single locality in the northwest at Enoch lake, 68°05'05"N 140°02'44"W (Cody et al. 1998).

Veratrum viride Ait. ssp. *eschscholtzii* (Gray) A. & D. Löve, White Hellebore — YUKON: moist draw in subalpine meadow, Kotaneelee Range, 60°14'31"N 124°07'19"W, B. Bennett 98-227, 19 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 300 kilometers to the southeast from a site in the vicinity of Francis Lake.

Zygadenus elegans Pursh, Mountain Death-camas — YUKON: at summit of hill by cliff overlooking Beaver River Hotsprings meadow, 66°22'53"N 125°34'33"W, B. Bennett 97-572, 15 Aug. 1997 (DAO).

The specimen cited above is an extension of the known range of about 100 kilometers from the easternmost location in the Yukon Territory mapped by Cody (1996).

ORCHIDACEAE

Calypso bulbosa (L.) Oakes, Fairy-slipper — YUKON: *Picea glauca* feathermoss forest, Tributary of Beaver River, 60°33'21"N 126°12'00"W, B. Bennett 98-288, 14 Aug. 1998 (DAO).

This species is not common in the Yukon Territory but is found as far north as Dawson (Cody 1996). The specimen cited above is an extension of the known range in the Territory of about 150 kilometers northeast of the vicinity of Watson Lake.

Cypripedium parviflorum (Salisb.) var. *makasin* (Farwell) Sheviak (*C. calceolus* L. ssp. *parviflorum* of recent authors), Small Yellow Lady's-slipper — YUKON: calcareous slope near treeline, Fishing Branch River, 66°23'N 139°22'W, J. Staniforth 97-40, 29 Aug. 1997 (DAO).

The specimen cited above is the northernmost yet collected in the Yukon Territory. Cody (1996) knew this species only as far north in the Territory as about latitude 66°N adjacent to the Alaska border.

Cypripedium passerinum Richards., Sparrow's-egg Lady's-slipper — YUKON: at summit of hill overlooking Beaver River between hotspring meadows, 60°22'53"N 125°34'33"W, B. Bennett 97-563, 15 Aug. 1997 (DAO).

The specimen cited above is an extension of the known range in southeastern Yukon Territory of some 175 kilometers southeast from areas adjacent to the Nahanni Range Road (Cody et al. 1998).

Goodyera repens (L.) R.Br., Dwarf Rattlesnake-plantain — YUKON: mature alluvial White Spruce forest, base of Bear Cave Mountain along the Fishing Branch River, 66°29'44"N 139°19'56"W, J. Staniforth 97-60, 29 Aug. 1997 (DAO).

The specimen cited above is the northernmost yet found in the Yukon Territory. The nearest site known to Cody (1996) was adjacent to the Dempster Highway about 125 kilometers to the south.

Platanthera hyperborea (L.) Lindl., Northern Green Orchid — YUKON: 65°50'N 134°51'W, S.C. Zoltai s.n., 10 July 1972 (CAFB, photo DAO).

This specimen which was collected in the vicinity of the Bonnet Plume River, intermediate between the two northernmost sites plotted by Cody (1996) in the southern Wernecke Mts. at 64°37'N 135°16'W and at Rampart House on the Alaska-Yukon border adjacent to the Porcupine River.

SALICACEAE

Salix pseudomonticola Ball, *S. monticola* sensu Cody (1966), Mountain Willow — YUKON: roadside SE of River, crest of hill, east of La Biche, 60°03'00"N 124°00'42"W, B. Bennett 97-346, 18 June 1997 (DAO); field at end of runway, La Biche Airstrip, 60°07'N 124°02'21"W, B. Bennett 97-338, 18 June 1997 (DAO).

The specimens cited above extend the known range of this species in the Yukon Territory about 100 kilometers eastward to the extreme southeast of the Territory.

Salix pseudomyrsinites Anderss., *S. novae-angliae* Anderss — YUKON: Bonnet Plume River, 65°01'N 135°05'W, P. Vernon s.n., 6 July 1961 (DAO); *Picea glauca*/Feathermoss forest, Rock River, 15 km N of Dalziel Creek, 60°43'N 127°12'W, G. Brunner s.n., 22 July 1994 (DAO); *Populus balsamifera*-*Salix* woodland, W shore Lower Toobally Lake, 60°12'N 126°20'W, G. Brunner s.n., 13 July 1994 (DAO); lakeside, Lee's Camp, Beaver River, 60°11'57"N 125°09'42"W, B. Bennett 97-431, 18 Aug. 1997 (DAO).

The first specimen cited above extends the known range in central Yukon Territory about 200 kilometers east of a site adjacent to the Dempster Highway mapped by Cody (1996). The other specimens cited above extend the known range in the southeast of the Territory about 200 kilometers east of the vicinity of Watson Lake.

Salix pyrifolia Anderss., Balsam Willow — YUKON: moist spruce forest, near Lee's Cabin, Beaver Creek, 60°10'30"N 125°20'W, B. Bennett 98-258, 12 June 1998 (DAO).

The specimen cited above which was considered rare in the Yukon Territory by Douglas et al. (1981) extends the known range in the Territory about 200 kilometers east from sites in the vicinity of Watson Lake.

MYRICACEAE

Myrica gale L., Sweet Gale — YUKON: in wet carr with *Carex* and *Vaccinium uliginosum*, 67°04'N 137°17'W, S.C. Zoltai s.n., 25 July 1972 (CAFB, photo DAO); wetland *Carex* fen, edge of Beaver pond, Ottertail Creek, west of Mt. Martin, 60°07'N 124°20'W, B. Bennett 98-256, 16 June 1998 (DAO).

The specimens cited above are the northernmost yet known from the Yukon Territory about 180 kilo-

meters north of the northernmost mapped by Cody (1996) and the easternmost yet known in the Territory about 175 kilometers east of a site west of longitude 127°W mapped by Cody (1996).

BETULACEAE

Betula occidentalis Hook., Water Birch — YUKON: *Betula glandulosa*, *Salix glauca*, *S. barclayi* shrub with *Picea glauca* and *Abies lasiocarpa* on slope, Kotaneelee Range, 60°14'45"N 124°08'03"W, B. Bennett 98-076, 20 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 260 kilometers east from the vicinity of Watson Lake (Cody 1996).

URTICACEAE

Parietaria pensylvanica Muhl., Pellitory — YUKON: under *Solidago* in field surrounding warm springs, Beaver River Hot Springs, 60°22'53"N 125°34'33"W, B. Bennett 97-585, 15 Aug. 1997 (DAO).

The only other known locality for this rare species in the Yukon Territory is Larsen Creek at 60°12'N 125°32'W (Scotter and Cody 1979). To the south in northeastern British Columbia it is found at the Liard Hot Springs.

Urtica dioica L. ssp. *gracilis* (Ait.) Selander, Common Nettle — YUKON: grassy meadow at edge of old oxbow slough, North Fork of the Fishing Branch River, 66°33'08"N 139°17'48"W, J. Staniforth 97-51, 29 Aug. 1997.

The only site for this species north of the vicinity of Dawson known to Cody (1996) was adjacent to the Porcupine River near the Alaska border. The specimen cited above was found about 125 kilometers southeast of the Porcupine River location.

SANTALACEAE

Geocaulon lividum (Richards.) Fern., Northern Comandra — YUKON: well drained slope, 65°33'N 134°54'W, S.C. Zoltai s.n., 7 July 1972 (CAFB, photo DAO); well drained shale gravel, Palmer Lake, 66°12'N 136°25'W, S.C. Zoltai s.n., 15 July 1972 (CAFB, photo DAO).

The specimens cited above were from sites about 175 kilometers northwest of a site adjacent to the Dempster Highway (Cody 1966). To the northwest about 200 kilometers this species is also known in the Yukon Territory from adjacent to the Porcupine River and near the Alaska border (Cody 1966).

POLYGONACEAE

Fagopyrum esculentum Moench, Buckwheat — YUKON: disturbed soil adjacent to cabin, Larsen Airstrip, 60°10'35"N 125°03'22"W, B. Bennett 97-605 (DAO).

This species which is an occasional escape from cultivation in southern Canada had not been

observed by the local resident in previous years. It has not previously been found in the Yukon Territory but has been collected in southern Alaska (Welsh 1974). *Fagopyrum esculentum*, which is an erect annual species may be distinguished from species of the genus *Polygonum* as follows:

- A. Leaves triangular-hastate to cordate; fruit exserted, twice as long as the perianth *Fagopyrum*
- A. Leaves various, if cordate, stems twining; fruit usually included in the perianth *Polygonum*

Polygonum buxiforme Small, Eastern Knotweed — YUKON: front yard of cabin, Lee's Camp, Beaver River, 60°11'57"N 125°09'42"W, B. Bennett 97-493, 18 Aug. 1997 (DAO).

This is a native weedy species that has not previously been recorded from southeastern Yukon Territory. The nearest sites known to Cody (1996) are from the vicinity of Johnson's Crossing and adjacent to the Canol Road, about 450 kilometers to the west and northwest.

Polygonum caurianum Robins. — YUKON: wet ditch beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, B. Bennett 97-156, 27 June 1997 (DAO); graminoid/sedge meadows at edge of lake to mud flats, south end of Stevens Lake, 61°41'14"N 137°30'12"W, Staniforth & Rosie 98-175, 28 Aug. 1998 (DAO).

The nearest known sites of this species in eastern Yukon Territory are adjacent to the northern section of the Canol Road (Cody 1996) about 475 kilometers to the northwest; in the west the second specimen cited above is intermediate between Haines Junction and the Alaska Highway north of 63°31'N latitude. This species was considered rare in the Territory by Douglas et al. (1981).

Polygonum fowleri Robinson, Fowler's Knotweed — YUKON: bare gravel areas, RCAF Station, Whitehorse, J.M. Gillett 3416, 20 June 1949 (DAO).

This specimen was originally determined as *Polygonum achoreum*. It should now be added to the flora of the Yukon Territory (Cody 1996) although it was presumably introduced and has not been found again in the Territory. *Polygonum fowleri* can be separated from *P. achoreum* by its smooth or somewhat roughened, but never papillose achenes.

Polygonum lapathifolium L. sl., Willow Weed — YUKON: dry floodplain north of Giltana Lake, 61°14'04"N 136°57'26"W, Staniforth & Rosie 98-143, 26 Aug. 1998 (DAO); pond edge, sedge meadow to dry lake bottom, Buffalo Lake, 61°25'22"N 137°01'44"W, Staniforth & Rosie 98-25, 25 Aug. 1998 (DAO); graminoid/sedge meadows at edge of lake to mud flats, south end of Stevens Lake, 61°41'40"N 137°30'12"W, Staniforth & Rosie 98-171, 28 Aug. 1998 (DAO).

This species which was considered rare in the Yukon Territory by Douglas et al. (1981) was known

to Cody (1996) only from the vicinities of Mayo and Carmacks. The specimens cited above extend the known range in the Territory about 100 kilometers to the south.

Polygonum viviparum L., Alpine Bistort — YUKON: on sheer rockface in seep, Beaver River Hanging Gardens, 60°20'51"N 125°39'21"W, B. Bennett 97-413, 14 Aug. 1997 (DAO); mesic slope open meadow with *Pinus contorta* and *Alnus incana*, Kotaneelee Range, 60°14'31"N 124°07'19"W, B. Bennett 98-140, 20 June 1998 (DAO).

This is a widespread species in the Yukon Territory but was not known to Cody (1996) east of about longitude 127°15'W. The specimens cited above extend the known distribution eastward about 180 kilometers.

Rumex salicifolius Weinm. ssp. *triangulivalvis* Danser, Willow Dock — YUKON: riverbar, Lower Beaver River, 60°02'00"N 124°31'40"W, B. Bennett 97-608, 20 Aug. 1997 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as near longitude 127°30'W. The specimen cited above extends the known range eastward about 160 kilometers.

CHENOPODIACEAE

Chenopodium album L., Lamb's Quarters — YUKON: in dry meadow adjacent to hot spring, Beaver River Hot Springs, 60°22'53"N 125°34'33"W, B. Bennett 97-601, 15 Aug. 1997 (DAO); Old Crow Airport, 67°34'N 139°51'W, N. Hughes s.n., 29 July 1997 (DAO).

This species which is introduced from Europe was not known to Cody (1996) to occur north of latitude 64°15'N or east of longitude 131°30'W. The specimens cited above extend the known range southeastward about 400 kilometers and northward about 400 kilometers.

Chenopodium dessicatum A. Nels. — YUKON: alkaline flat, Takhini Salt Flats, 60°51'N 135°43'W, B. Bennett 98-431, 16 Aug. 1998, (DAO).

Cody (1996) knew this species in the Yukon Territory from only three localities in the Territory: Dawson, Carmacks and adjacent to the Tagish Road northeast of Carcross and suggested that it might be a casual introduction. The site reported above is west of Whitehorse.

CARYOPHYLLACEAE

Cerastium arvense L., Field Chickweed — YUKON: at base of slope beside hot springs, Beaver River Hot Springs, 60°22'53"N 125°34'33"W, B. Bennett 97-521, 15 Aug. 1997 (DAO); silty sand on river bar, La Biche River, 60°13'58"N 124°13'58"W, B. Bennett 98-097, 18 June 1998 (DAO).

This species was previously known in the Yukon Territory only as far east as the upper Canol Road. The specimen cited above extends the known range



FIGURE 3. *Cerastium nutans*. (Drawn by Valerie Fulford).

in the Territory about 475 kilometers to the south-east.

Cerastium nutans Raf., Nodding Chickweed — YUKON: along gravel roadside, Frances Lake West Arm, R. Rosie 27NM, 31 July 1974 (DAO).

This specimen was originally identified as *Cerastium beeringianum* but has recently been revised to *C. nutans* by J. K. Morton and is the first record of its occurrence in the Yukon Territory. Porsild and Cody (1980) considered this species to be a recent introduction in southwestern District of Mackenzie. It is an annual species with erect, glandular-hirsute stems, linear-lanceolate leaves, an open cymose terminal inflorescence and nodding mature capsules.

Minuartia elegans (Cham. & Schlecht.) Schischk., Northern Sandwort — YUKON: alpine, in sand at base of eroding cliff, Beaver River Ridge, 60°12'N 124°35'W, B. Bennett 98-517, 16 Aug. 1998 (DAO); windblown ridge, submesic rocky outcrop, Kotaneelee Range, 60°13'08"N 124°06'36"W, B. Bennett 98-033, 20 June 1998 (DAO).

The specimens reported above extend the known range in the Yukon Territory (Cody 1996) about 200

kilometers to the east from a site west of longitude 127°W.

Minuartia rubella (Wahlenb.) Graebn. ex Asch. & Graebn., Boreal Sandwort — YUKON: slope on edge of dry ridge, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett* 98-087, 20 June 1998 (DAO); moist crevices in talus, same locality, *B. Bennett* 98-521, 19 June 1998 (DAO).

The specimens cited above extend the known range in the Yukon Territory (Cody 1996) about 200 kilometers to the east from a site west of longitude 127°W.

Minuartia yukonensis Hultén — YUKON: arctic tundra, Richardson Mts., 66°17'N 136°11'W, *S.C. Zoltai s.n.*, 19 July 1972 (CAFB, photo DAO).

The specimen cited above is intermediate between latitudes 63°59'N and 67°42'N about 280 kilometers to the south and 150 kilometers to the north.

Sagina saginoides (L.) Karst, Arctic Pearlwort — YUKON: steep talus slope, Beavercrew Ridge, 60°13'N 124°32'W, *B. Bennett* 98-519, 15 Aug. 1998 (DAO).

This is an uncommon species in the Yukon Territory known only in the area east of the Canol Road (Cody 1996). The specimen cited above is an extension of the known range of about 250 kilometers east of a site west of Watson Lake.

Silene involucrata (Cham. & Schlecht.) Bocquet ssp. *involutrata*, Arctic Campion — YUKON: alpine meadow near creek just north of Mt. Merrill, Beavercrew Ridge, 60°11'N 124°36'W, *B. Bennett* 98-523, 16 Aug. 1998 (*B. Bennett* Herbarium, photo DAO); subalpine meadow with *Vaccinium caespitosum* on mesic slope, Kotaneelee Range, *B. Bennett* 98-525, 19 June 1998 (DAO).

Cody (1996) knew this species in the Yukon Territory only from west of longitude 130°W. The nearest record to the specimens cited above is about 400 kilometers to the northwest.

Stellaria longifolia Muhl., Long-leaved Chickweed — YUKON: Old Crow Flats, 68°0.597'N 140°28.01'W, *J. Hawkings s.n.*, 27 July 1997 (DAO).

This is the northernmost collection of this species yet found in the Yukon Territory. It is an extension of the known range to the northwest of about 40 kilometers from a site adjacent to the Old Crow River.

CERATOPHYLLACEAE

Ceratophyllum demersum L., Hornwort — YUKON: aquatic, Lee's Lake, Beaver River, 60°10'30"N 125°07'44"W, *R. Rosie* 98-242, 12 June 1998 (*B. Bennett* Herbarium, photo DAO).

Cody (1994) reported the first published localities of this species in the Yukon Territory (north of the

Porcupine River and southwest of Mayo). The specimen cited above is an extension of the known range in the Yukon Territory of about 650 kilometers to the extreme southeast.

NYMPHAEACEAE

Nuphar polysepalum Engelm., Yellow Pond-lily — YUKON: in water, 66°12'N 136°25'W, *S.C. Zoltai s.n.*, 16 July 1972 (CAFB, photo DAO).

The specimen cited above is from a site intermediate between a location at Dempster Highway Mile 75, about 175 kilometers to the southwest and locations along the Porcupine River about 125 kilometers to the north (Cody 1996).

RANUNCULACEAE

Aconitum delphinifolium DC. ssp. *paradoxicum* (Rchb.) Hultén, Mountain Monkshood — YUKON: moist, imperfectly drained area, 67°19'N 136°47'W, *S.C. Zoltai s.n.*, 2 Aug. 1971 (CAFB, photo DAO); alpine meadow, 67°05'N 136°16'W, *S.C. Zoltai s.n.*, 26 July 1972 (CAFB, photo DAO).

The specimens cited above are the southernmost yet found in the Richardson Mountains in the Yukon Territory. To the south at Sheep Mountain in the Ogilvie Mountains adjacent to the Dempster Highway Brooke and Kojima (1985) reported a collection which was not mapped by Cody (1996).

Anemone narcissiflora L. sl., Narcissus Anemone — YUKON: mesic meadow at camp, Kotaneelee Range, 60°14'45"N 124°08'03"W, *B. Bennett* 98-157, 20 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 300 kilometers to the southeast from the vicinity of Francis Lake.

Anemone parviflora Michx., Northern Anemone — YUKON: subalpine in *Abies lasiocarpa* krumholtz, Beavercrew Ridge, 60°11'N 124°35'W, *B. Bennett* 98-298, 16 Aug. 1998 (DAO); moist subalpine channel, Kotaneelee Range, 60°14'31"N 124°07'10"W, *B. Bennett* 98-103, 20 June 1998 (DAO).

The specimens cited above extend the known range in the Yukon Territory (Cody 1996) about 200 kilometers to the east from a site west of longitude 127°W.

Anemone richardsonii Hook., Yellow Anemone — YUKON: steep scree slope—old burn, Beaver River, 60°26'44"N 125°48'05"W, *B. Bennett* 97-473, 14 Aug. 1997 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as adjacent to the Hyland River. The specimen cited above is an extension of the known range in the Territory of about 125 kilometers to the east.

Caltha natans Pall., Floating Marsh-marigold — YUKON: Wetland *Carex* fen, edge of beaver pond in mud with *Sparganium angustifolium*, Ottertail

Creek, west of Mt. Martin, 60°07'00"N 124°15'20"W, *B. Bennett* 98-268, 16 June 1998 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The specimen cited above is an extension of the known range in the Territory of about 750 kilometers from a site south of Mayo mapped by Cody (1996).

Caltha palustris L. ssp. *arctica* (R.Br.) Hultén, Marsh-marigold — YUKON: near Wind River, 65°48'N 135°12'W, *S.C. Zoltai s.n.*, 7 July 1972 (CAFB, photo DAO).

All sites in the Yukon Territory known to Cody (1996) were west of longitude 137°W. The locality cited above is about 125 kilometers east of the nearest known location in the Territory. It is however known in the District of Mackenzie to the east about 100 kilometers at 66°03'N 133°09'W.

Ranunculus flammula L., Creeping Spearwort — YUKON: submerged in subalpine pond, Kotaneelee Range, 60°14'45"N 124°08'03"W, *B. Bennett* 98-042, 21 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 180 kilometers to the east from a site mapped by Cody (1996) west of longitude 127°W.

Thalictrum sparsiflorum Turcz. ssp. *richardsonii* (Gray) Cody, Few-flowered Meadowrue — YUKON: meadows surrounding warm spring, Beaver River Hotsprings, 60°22'53"N 125°34'33"W, *B. Bennett* 98-312, 14 Aug. 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 100 kilometers from a site mapped by Cody (1996) west of longitude 127°W.

BRASSICACEA (CRUCIFERAE)

Alyssum obovatum (C.A. Meyer) Turcz. — G. A. Mulligan, following R. C. Rollins (1993) has revised all specimens mapped in Cody (1996) under *A. americanum* to *A. obovatum*.

Arabis divaricarpa A. Nels. var. *dacotica* (Greene) B. Boivin, Spreading-pod Rockcress — YUKON: riverbar, Beaver River Camp #1, 60°30'40"N 126°06'26"W, *B. Bennett* 97-498B, 12 Aug. 1997 (DAO); riverbar in sand, La Biche River Camp #1, *B. Bennett* 97-301, 12 June 1997 (DAO).

The specimens cited above extend the known range of this taxon in the Yukon Territory (Cody 1996) about 575 kilometers east from a site about 140°W longitude.

Arabis glabra (L.) Bernh., Tower Mustard — YUKON: area surrounding beaver pond, Larsen Hotsprings Lower Pool, *B. Bennett* 97-489, 20 Aug. 1997 (DAO).

Cody (1994, 1996) suggested that a specimen collected at Johnson's Crossing was probably intro-

duced. The specimen cited above however from adjacent to a beaver pond at the Larsen Hotsprings about 450 kilometers to the east is undoubtedly native and this species should be added to the list of rare plants in the Yukon Territory (Douglas et al. 1981).

Arabis holboellii Hornem. var. *retrofracta* (Grah.) Rydb., Holboell's Rockcress — YUKON: riverbar, Beaver River Camp #1, *B. Bennett* 97-498A, 12 Aug. 1997 (DAO).

The specimen cited above is an extension of the known range of about 150 kilometers east of a site about longitude 127°44'W in the Yukon Territory.

Descurainia incana (Bernh. ex Fisher & C. A. Meyer) Dorn, Gray Tansy Mustard — YUKON: silty sand on riverbar, La Biche River, 60°13'58"N 124°13'58"W, *B. Bennett* 98-096, 18 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 200 kilometers to the east of longitude 127°35'W.

Draba corymbosa R.Br. ex DC. — YUKON: dry sand over talus, north of Wind River, 65°16'N 135°56'W, *S.C. Zoltai s.n.*, 2 July 1972 (CAFB, photo DAO).

Cody (1996) knew this species in the Yukon Territory only west of longitude 137°W. The specimen cited above is an extension of the known range in the Territory of about 100 kilometers east of a site adjacent to the Dempster Highway.

Draba densifolia Nutt., Nuttall's Draba — YUKON: terraced ramp, Ogilvie Mountains, Tombstone Region, 64°26'34"N 138°45'49"W, *C. Grieser, plot 10*, 30 June 1997 (DAO); upper scree slope, Ogilvie Mountains, Tombstone Region, 64°24'24"N 138°41'29"W, *C. Grieser, plot 24*, 1997 (DAO).

These are the first and only known records of this species occurring in the Yukon Territory and should be added to the list of rare plants in the Territory (Douglas et al. 1981). Hultén (1968) mapped only four localities in central eastern Alaska to the west of the localities cited above, and then it is disjunct to south-central and south-eastern British Columbia, where considered rare (Douglas et al. 1998), south-western Alberta and south to Wyoming, Utah and California. *Draba densifolia* may be separated from other species found in the Tombstone Region as follows:

- A. Petals narrower than sepals; stigma capitate *D. stenopetala*
- A. Petals broader than sepals; stigma bilobed
 - B. Style over 0.5 mm long *D. densifolia*
 - B. Style less than 0.5 mm long *D. alpina* and *D. corymbosa*

Draba paysonii Macbride — Douglas and Ruyle-Douglas (1978) reported this species as new to the Yukon Territory on the basis of a specimen (Douglas

et al. 9834, DAO, GD) from Hoge Creek, Klauane National Park which was identified by G. A. Mulligan in 1977. It was thus included in the list of rare plants of the Yukon Territory (Douglas *et al.* 1981) and the Flora of the Yukon Territory (Cody 1996). In 1997 however Mulligan revised this specimen to *D. ruaxes* Payson & St. John. It therefore must be deleted from the list of rare plants and the flora.

Erysimum coarctatum Fern. — Specimens from the Yukon Territory, Continental Northwest Territories, Alberta and British Columbia, previously determined as *E. inconspicuum* (S. Wats.) MacM. have been revised to *E. coarctatum* by G.A. Mulligan. These two species can be separated as follows:

- A. Limb of petals 2.5–3 mm long, 1.5–2 mm broad; fruiting raceme elongate (up to 2 or 3 dm long) and open; siliques about 1 mm broad; seeds 1–1.3 mm long *E. inconspicuum*
- A. Limb of petals 4.5–6 mm long, 2–3 mm broad; fruiting raceme crowded and corymbiform at summit; siliques 1.5–2 mm broad; seeds 1.6–2 mm long *E. coarctatum*

Erysimum inconspicuum should be deleted from the floras of the Yukon Territory and Continental Northwest Territories.



FIGURE 4. *Draba densifolia* (Drawn by Lee Mennell).

Lesquerella arctica (Wormskj.) S. Wats. ssp. *arctica*, Arctic Bladderpod — YUKON: Rancheria River up slope on N side of Highway, 60°05'10"N 130°25'37"W, *C.J. Keddy* 98-H-1, 30 July 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 200 kilometers from sites adjacent to the Canol Road southwest of Ross River.

Parrya arctica R.Br. — Cody (1994) cited a specimen of this species (*P.F. Cooper* 433) which was collected on Herschel Island in 1979. It is the only known record for the Yukon Territory. Unfortunately this specimen was indicated as being preserved in DAO but should have been CAN.

Parrya nudicaulis (L.) Regel, Northern Parrya — YUKON: closed mixed Trembling Aspen-White Spruce, ESE of Teslin, 60°05'55"N 132°22'51"W, *C.J. Keddy* 98-4-6, 26 July 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 160 kilometers south from sites adjacent to the Canol Road southwest of Ross River.

Rorippa barbareaifolia (DC.) Kitagawa, Hoary Yellow Cress — YUKON: imperfectly drained silty loess on seismic line, 66°53'N 136°55'W, *S.C. Zoltai s.n.*, 22 July 1972 (CAFB, photo DAO).

The specimen cited above is intermediate between Dempster Highway Mile 96 and 67°38'N 137°17'W in the Richardson Mountains (Cody 1996). This location is about 180 kilometers north of Mile 96 and in the southern Richardson Mountains about 125 kilometers from the nearest northern site.

Subularia aquatica L. ssp. *americana* Mulligan & Calder, Alwort — YUKON: level poorly drained silty soil, N shore of Teslin Lake, 60°10'17"N 132°42'27"W, *C.J. Keddy* 98-66-1, 30 July 1998 (DAO); fluvial flood zone below Johnson's Crossing bridge, 60°29'N 133°18'W, *J. Grods* 98-9-2, 27 July 1998 (DAO).

This species is currently known from only seven localities in southern Yukon Territory. The specimens cited above are southward of the previously known range in the Territory (Cody 1996) of about 150 kilometers south of sites adjacent to the Canol Road.

DROSERACEAE

Drosera anglica Huds., Great Sundew — YUKON: in bog pool with *Carex* and *Drepanocladus*, 65°44'N 136°06'W, *S.C. Zoltai s.n.*, 22 July 1972 (CAFB, photo DAO); in bog pool with *Sphagnum*, 67°08'N 137°23'W, *S.C. Zoltai s.n.*, 24 July 1972 (CAFB, photo DAO).

This species, which was considered rare in the Yukon Territory by Douglas *et al.* (1981), was previously known north of latitude 64°N only from adja-

cent to the Caribou River close to the District of Mackenzie border.

Drosera rotundifolia L., Round-leaved Sundew — YUKON: wet organic soil with *Sphagnum* and *Carex*, 65°47'N 136°42'W, S.C. Zoltai s.n., 21 July 1972 (CAFB, photo DAO).

The specimen cited above is from a location intermediate between just north of latitude 64°N and just north of latitude 67°N (Cody 1996).

CRASSULACEAE

Rhodiola rosea (L.) Scop. ssp. *integrifolia* (Raf.) Hara, Roseroot — YUKON: rock ledge in river gorge, Richardson Mts., 66°13'N 136°02'W, S.C. Zoltai s.n., 17 July 1972 (CAFB, photo DAO).

The specimen cited above is from a site intermediate between locations in northern Yukon Territory north of latitude 65°N and south of latitude 68°N (Cody 1996).

SAXIFRAGACEAE

Mitella pentandra Hook., Five-stamened Mitrewort — YUKON: stream bank, 8 km S of centre of McNeil Lake, 61°15'10"N 131°51'28"W, C.J. Keddy 98-D-1, 8 Aug. 1998 (DAO); open forest in subalpine zone, Cassiar Mountains, Dorsey Range, C. Zoladeski 98-20-2, 31 July 1998 (DAO).

This is a rare species in the Yukon Territory (Douglas et al. 1981). The specimens cited above extend the known range in the Territory about 175 kilometers southeast and southwest from sites about latitude 61°25'N.

Parnassia fimbriata Koenig, Fringed Grass-of-Parnassus — YUKON: alpine tundra, old mining road W of ca 100 km N of camp ground on Nahanni Range Road, 61°23'N 128°22'W, C. Zoladeski s.n., 12 Aug. 1995 (DAO); moist subalpine small river channel, Kotaneelee Range, 60°14'31"N 124°07'19"W, B. Bennett 98-151, 20 June 1998 (DAO).

The specimens cited above extend the known range of this species about 325 kilometers to the southeast of a Francis lake site mapped by Cody (1996).

Saxifraga aizoides L., Yellow Mountain Saxifrage — YUKON: on sheer rockface in seep, Beaver River, Hanging Gardens, 60°20'51"N 125°39'21"W, B. Bennett 97-414 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The nearest site to the locality cited above known to Cody (1996) was adjacent to the Canol Road at approximately longitude 133°W, about 425 kilometers to the northwest.

Saxifraga cernua L., Nodding Saxifrage — YUKON: subalpine in crack in talus, Kotaneelee Range, 60°13'08"N 124°06'36"W, B. Bennett 98-163, 20 June 1998.

The specimen cited above is an extension of the known range in the Yukon Territory of about 450 kilometers east of a site mapped by Cody (1996) west of longitude 130°W.

Saxifraga foliolosa R.Br., Foliose Saxifrage — YUKON: alpine tundra, wet rich tundra below cirque, mountain between Kusawa and Jojo lakes, 60°35'47"N 136°15'19"W, B. Bennett 97-649, 19 Sept. 1997 (DAO).

The only site of this rare plant in southwestern Yukon Territory known to Cody (1996) was near Mile 100 Haines Highway, about 50 kilometers southwest of the locality cited above. It is also known in the northern part of the Territory north of latitude 67°N.

Saxifraga nelsoniana D.Don ssp. *pacifica* (Hultén) Hultén, Cordate-leaved Saxifrage — YUKON: mountain between Kusawa and Jojo lakes, 60°35'47"N 136°15'19"W, B. Bennett 97-638, 19 Sept. 1997 (DAO).

This subspecies was considered rare in the Yukon Territory (Douglas et al. 1981). The nearest known site to the locality cited above is about 60 kilometers to the southwest adjacent to the Haines Highway.

Saxifraga razshivinii Zhmylev, *S. davurica* Willd. ssp. *grandipetala* sensu Porsild and Cody 1980 — YUKON: subalpine forest, *Picea glauca*, *Abies lasiocarpa*, *Salix*, Beavercrow Ridge, 60°12'N 124°35'W, B. Bennett 98-514, 16 Aug. 1998 (DAO).

Cody (1996) knew this species in the Yukon Territory only west of longitude 134°W although Porsild and Cody (1980) knew it throughout much of the Mackenzie Mountains in western District of Mackenzie. The specimen cited above is an extension of the known range in the Territory of about 675 kilometers to the east and southeast.

ROSACEAE

Dryas crenulata Juz. — YUKON: at base of talus near summit, Kotaneelee Range, 60°13'08"N 124°06'36"W, B. Bennett 98-148, 20 June 1998 (DAO).

The specimen cited above is an extension of the known range of this species in the Yukon Territory of about 550 kilometers from a site mapped by Cody (1996) west of longitude 133°W.

Dryas hookeriana Juz., Hooker's Mountain Avens — YUKON: abundant on tundra, Mount Haldane, 63°52'N 135°46'W, R. Rosie 1801, 24 July 1986 (DAO); imperfectly drained loam, Dempster Hwy., Ogilvie Mts., 64°30'N 138°13'W, S.C. Zoltai s.n., 11 June 1975 (CAFB, photo DAO); dry fine sand, north of Wind River, 65°16'N 135°56'W, S.C. Zoltai s.n., 2 July 1972 (CAFB, photo DAO); moist slope, near the Firth River, 69°12'N 139°24'W, S.C. Zoltai 172 #35, 6 July 1973 (CAFB, photo DAO).

The specimens cited above extend the known range in the Yukon Territory to the extreme north.

The northernmost site mapped by Cody (1996) was from adjacent to the Bonnet Plume River at 64°56'N 133°50'W.

Dryas integrifolia M. Vahl ssp. *integrifolia* — YUKON: dry ridge, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett* 98-088, 20 June 1998 (DAO).

The specimen cited above is an extension of the known range of this species in the Yukon Territory (Cody 1996) of about 180 kilometers east of a site west of longitude 127°W.

Dryas integrifolia M. Vahl ssp. *sylvestris* var. *sylvatica*, Entire-leaved White Mountain-avens — YUKON: dry talus hillside, Beaver River, 60°30'40"N 126°06'26"W, *B. Bennett* 97-554 (DAO).

The nearest location to the specimen cited above known to Cody (1996) was collected in the vicinity of Frances Lake about 200 kilometers to the northwest.

Fragaria virginiana Duchesne ssp. *glauca* (S. Wats.) Staudt, Wild Strawberry — YUKON: well drained, gravel river terrace, 65°50'N 134°51'W, *S.C. Zoltai s.n.*, 10 July 1972 (CAFB, photo DAO).

The specimen cited above from the lower Eagle River area is now the northmost known location in the Yukon Territory about 250 kilometers north of the nearest site near Faro (Cody 1996).

Geum macrophyllum Willd. ssp. *perincisum* (Rydb.) Hultén, Large-leaved Avens — YUKON: riverbar at campsite, La Biche Camp, 60°00'07"N 124°06'00"W, *B. Bennett* 97-370, 13 June 1997 (DAO).

The specimen cited above is an extension of the known range of about 175 kilometers from a location plotted by Cody (1996) in southeastern Yukon Territory.

Potentilla litoralis Rydb. — YUKON: dry slopes in upper canyon with *Artemisia*, Beaver River, 60°21'14"N 125°20'57"W, *B. Bennett* 97-480, 17 Aug. 1997 (DAO); dry steep sedimentary slope, Beaver River above lower rapids, 60°01'37"N 124°36'38"W, *B. Bennett* 97-582, 19 Aug. 1997 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as about longitude 127°45'W. The specimens cited above are an extension of the known range in the Territory of about 180 kilometers to the east.

Sibbaldia procumbens L., *Sibbaldia* — YUKON: moist draw in subalpine meadow, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett* 98-221, 19 June 1998 (DAO); dwarf willow - *Luetkea pectinata*/moss habitat, W on old mining road until mountain pass ca 10 km N of Camp Ground on Nahanni Range Road, 61°23.40'N 128°22.31'W, *C. Zoladeski s.n.*, 12 Aug. 1995 (DAO); alpine

graminoid meadow/shrub rich of *Festuca altaica* - *Phyllodoce glanduliflora*/*Salix*/moss, near above locality, 61°23.34'N 128°23.05'W, *C. Zoladeski s.n.*, 12 Aug. 1995 (DAO); Quartz Creek, 60°21'N 127°57'W, *C. Zoladeski* 265-1-4, 23 July 1994 (DAO).

The specimens cited above are an extension of the known range in the Yukon Territory of about 280 kilometers east and southeast of sites adjacent to Francis Lake mapped by Cody (1996).

FABACEAE (LEGUMINOSAE)

Astragalus australis (L.) Lam., Indian Milk-vetch — YUKON: gravel bar in river by hot springs, Beaver River Hot springs, 60°22'53"N 125°34'33"W, *B. Bennett* 97-529, 15 Aug. 1997 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as longitude 127°48'W. The specimen cited above is an extension of the known range in the Territory of about 125 kilometers to the east.

Astragalus umbellatus Bunge, Liquorice-root — YUKON: subalpine moist herb meadow, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett* 98-055, 20 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 350 kilometers southeast of a site in the vicinity of Francis Lake mapped by Cody (1996).

Caragana arborescens Lam., Common Caragana — YUKON: roadsides, an occasional escape about town, Dawson, *Calder and Billard* 3202, 20 June 1949 (DAO).

This introduced species was unfortunately missed during the writing of the Flora of the Yukon Territory. It is the only woody legume yet known in the region.

Lathyrus ochroleucus Hook., Cream-flowered Peavine — YUKON: dry steep hillside next to warm springs, Beaver River Hot springs, 60°22'53"N 125°34'33"W, *B. Bennett* 97-599, 15 Aug. 1997 (DAO).

Cody et al. (1998) reported this species which is rare and new to the Yukon Territory. The specimen cited above is the fourth collected in the Territory and an extension of the known range about 50 kilometers to the northwest of the previously known localities.

Lupinus arcticus Wats., Arctic Lupine — YUKON: mixed *Picea glauca*, *Pinus contorta* forest, Larsen Airstrip, 60°10'35"N 125°03'22"W, *B. Bennett* 98-253, 12 June 1998 (DAO); mesic meadow at camp, Kotaneelee Range, 60°14'45"N 124°18'03"W, *B. Bennett* 98-156, 20 June 1998 (DAO).

This is a widespread species in the Yukon Territory (Cody 1996). The specimens cited above however extend the known range in the Territory

almost 100 kilometers to the extreme east of the region.

Oxytropis nigrescens (Pall.) Fisch. ssp. *nigrescens*, Blackish Locoweed — YUKON: dry exposed alpine ridge, Beavercrow Ridge, 60°13'N 124°31'W, *B. Bennett* 98-384, 15 Aug. 1998 (DAO); windblown ridge, submesic rocky, Kotaneelee Range, 60°13'08"N 124°06'36"W, *B. Bennett* 98-112, 20 June 1998 (DAO).

The specimens cited above extend the known range in the Yukon Territory about 200 kilometers to the east from a site mapped by Cody (1996) west of longitude 127°W.

Oxytropis sericea Nutt. ssp. *spicata* (Hook.) Cody, Silky Locoweed — YUKON: sage/grass slope, Buffalo Lake, 61°22'22"N 137°01'44"W, *Staniforth & Rosie* 98-52, 25 Aug. 1998 (DAO).

This is a rare species in the Yukon Territory (Douglas et al. 1981). The nearest sites known to Cody (1996) are in the Kluane Region about 120 kilometers to the west and adjacent to the Alaska Highway about 340 kilometers to the southeast.

Trifolium cyathiferum Lindl., Cup Clover — YUKON: W. Dawson, *E. Schoff*, 1904 (TRT, DAO).

This species which is rare on southern Vancouver Island and southeastern British Columbia occurs south to Idaho and California. It was reported as occurring in the Yukon Territory by Boivin (1966) where it was presumably introduced in the vicinity of Dawson but has not been found in the Territory since 1904.

Cup Clover is an annual involucrate species, with glabrous or subglabrous shallowly round-lobate involucre and the lobes finely erose-dentate.

Trifolium hybridum L., Alsike Clover — YUKON: field at end of runway, La Biche Airstrip, 60°07'42"N 124°02'21"W, *B. Bennett* 97-340, 18 June 1997 (DAO).

Cody (1996) knew this species which is naturalized from Europe only as far east in the Yukon Territory as adjacent to the Alaska Highway at 127°44.5'W. The specimen cited above is an extension of the known range in the Territory of about 225 kilometers to the east.

Trifolium pratense L., Red Clover — YUKON: disturbed area beside airstrip, La Biche Airstrip, 60°07'32"N 124°02'21"W, *B. Bennett* 98-224, 14 June 1998 (DAO).

The nearest site in the Yukon Territory of this introduced species known to Cody (1996) is southeast of Johnson's Crossing, about 500 kilometers west of the specimen cited above.

Vicia americana Muhl., American Vetch — YUKON: in yard around house, Watson Lake, 60°03'N 128°42'W, *R. Rosie* 1978, 22 July 1997 (DAO).

This species was previously only known in the extreme southeast of the Yukon Territory: La Biche

and Beaver rivers (Cody et al. 1998) and Larsen Creek (Scotter and Cody 1979). The specimen cited above extends the known range westward about 180 kilometers.

Vicia cracca L., Tufted Vetch — YUKON: edge of walkway, Wye Lake, 60°03'45"N 128°42'20"W, *B. Bennett* 98-354, 8 July 1998 (DAO).

This introduced species was previously known in the Yukon Territory only from the vicinity of Dawson (Cody 1996).

GERANIACEAE

Geranium richardsonii Fisch. & Trautv., Richardson's Geranium — YUKON: moist draw in subalpine meadow, Kotaneelee Range, 60°14'31"N 124°07'19"W, *B. Bennett* 98-281, 19 June 1998 (DAO).

This is a rare species in the Yukon Territory (Douglas et al. 1981). Cody (1996) knew it only from five localities, all south of latitude 64°N. The nearest site to the specimen cited above was from the Larsen Creek Hot Springs (Scotter and Cody 1979).

CALLITRICHACEAE

Callitriche anceps Fern., Two-edged Water-Starwort — YUKON: Lake margin, shallow, mud bottom, Mush Lake, 60°18'N 137°26'W, *R.D. Wickstrom* 398.4, 21 Aug. 1973 (DAO).

Douglas et al. (1981) knew this rare species in the Yukon Territory only from adjacent to the Canol Road. Cody et al. (1998) extended the known range eastward to a site adjacent to the southern Campbell Highway at 60°09'32"N 128°56'45"W. The specimen cited above is an extension of the known range westward about 250 kilometers and it is new to Kluane National Park.

ANACARDIACEAE

Rhus radicans L., Poison Ivy — YUKON: dry south-facing slope adjacent to hot spring, Larsen Hot Springs Lower Pool, 60°12'N 125°32'W, *B. Bennett* 97-512, 20 Aug. 1997 (DAO).

This species is new to the known flora of the Yukon Territory and should be added to the list of rare plants in the Territory (Douglas et al. 1981). It is an extension of the known range of about 1000 kilometers from sites adjacent to the North Saskatchewan River (Packer 1983). In British Columbia it is known only in the southeastern and southcentral regions (Douglas et al. 1989).

BALSAMINACEAE

Impatiens ? capensis Meerb., Spotted Touch-me-not — YUKON: roadside ditch west of bridge, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 98-285, 15 June 1998 (DAO).

Cody (1996) suggested that this species should be expected to be found in extreme southeastern Yukon Territory on the basis of a specimen collected by

W.W. Jeffreys in the District of Mackenzie about 6 km north of the British Columbia border and 3 km from the Yukon border. Unfortunately the specimen cited above is lacking flowers and could not be verified to species.

VIOLACEAE

Viola epipsela Ledeb. ssp. *repens* (Turcz.) Becker, Dwarf Marsh Violet — YUKON: wet organic over gravel, near Snake River, 65°51'N 133°09'W, S.C. Zoltai s.n., 14 July 1972 (CAFB, photo DAO); wet organic soil with *Sphagnum* and *Carex*, west of Peel River, 66°32'N 134°28'W, S.C. Zoltai s.n., 23 June 1972 (CAFB, photo DAO).

The specimens cited above from near the District of Mackenzie border were found in a large area where they were previously unknown in the Yukon Territory between latitudes 64°32'N and 67°N (Cody 1996).

Viola nephrophylla Greene, Northern Bog Violet — YUKON: on slope above hot springs, Beaver River Hot springs, 60°22'53"N 125°34'33"W, B. Bennett 97-542, 15 Aug. 1997 (DAO).

Cody et al. (1998) reported the second known site of this species in the Yukon Territory from Mount Billings, about 150 kilometers north of the only previously known site in the vicinity of Watson Lake. The specimen cited above is an extension of the

known range of this rare species in the Territory of about 175 kilometers to the east of Watson Lake.

ELAEAGNACEAE

Elaeagnus commutata Bernh., Silverberry — YUKON: dry south-facing slope with *Artemisia*, Beaver River Lower Canyon, 60°09'09"N 124°55'16"W, B. Bennett 97-484, 19 Aug. 1997 (DAO).

Cody et al. (1998) reported a small patch of this shrub on the bank of the La Biche River in the extreme east of the Yukon Territory, an eastward extension of the known range in the Territory of about 600 kilometers. The specimen cited above is an additional record in the southeast, about 40 kilometers west of the La Biche River site.

ONAGRACEAE

Circaea alpina L. ssp. *alpina*, Enchanter's-nightshade — YUKON: rare in this area, Beaver River Hot springs, 60°22'53"N 125°34'33"W, B. Bennett 98-293, 14 Aug. 1998 (DAO).

The specimen cited above is only the fifth yet found of this rare species in the Yukon Territory (Scotter and Cody 1979; Cody et al. 1998).

Epilobium hornemannii Rchb., Hornemann's Willowherb — YUKON: grassy meadow at edge of slough, river floodplain, North Fork of the Fishing Branch River, 66°33'08"N 139°17'48"W, J. Staniforth 97-53, 29 Aug. 1997 (DAO).

The specimen cited above is the northernmost yet collected in the Yukon Territory. It is an extension of the known range in the Territory to the north about 230 kilometers from a site adjacent to the Dempster Highway.

HALORAGACEAE

Myriophyllum sibiricum Komarov, Siberian Water-milfoil — YUKON: edge of old gravel pit with beaver lodge, La Biche River, 60°03'N 124°00'W, B. Bennett 97-316, 25 June 1997 (DAO).

The specimen cited above is an extension of the known range eastward in Yukon Territory of about 180 kilometers from a location mapped by Cody (1996) at about longitude 127°15'W.

APIACEAE (UMBELLIFERAE)

Angelica lucida L., Seacost Angelica — YUKON: north end of Wolf lake, 60°43'30"N 131°39'00"W, Mulder & Marion 98-574, 9 June 1998 (DAO).

This species which was considered rare in the Yukon Territory by Douglas et al. (1981) was known to Cody (1996) from only three sites. Cody et al. (1998) extended the known range in the Territory to the extreme southeast. The specimen cited above was collected from an area intermediate from the four previously known sites.

Cicuta bulbifera L., Bulbous Water-hemlock — YUKON: floating on surface of pond, Lee's Camp,



FIGURE 5. *Rhus radicans* (Drawn by Lee Mennell).

Beaver River, 60°11'57"N 125°09'42"W, *B. Bennett* 97-462, 18 Aug. 1997 (DAO); warm seep on edge of ridge, Beaver River Hotsprings, 60°22'53"N 125°34'33"W, *B. Bennett* 98-330, 11 Aug. 1998 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The specimens cited above are an extension of the known range in the Territory of about 150 kilometers to the east from a location plotted by Cody (1996) about longitude 127°36'W.

Cicuta maculata L. var. *angustifolia* Hook., Spotted Water-hemlock — YUKON: in meadow downstream of beaver pond, Larsen Hotsprings Lower Pool, 60°12'N 125°32'W, *B. Bennett* 98-336, 14 Aug. 1998 (DAO); in forest meadow, old channel, with *Glyceria pulchella* and *Carex arcta*, Nisutlin River Delta, 60°15'N 132°34'W, *B. Bennett* 98-187, 31 July 1998 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The first specimen cited above is a new record in the southeast of the Territory; the second specimen is intermediate between a site adjacent to the Klondike Highway north of latitude 62°N and a site west of longitude 127°W (Cody 1996).

Sium suave Walt., Water-parsnip — YUKON: Nordenskiöld River below Montague Mtn., 61°51'21"N 136°06'08"W, *M. Dennington Nord-47*, 15 July 1982 (DAO).

This is a rare species in the Yukon Territory which was previously known from sites in the Klondike Valley and sites just north of 60°N latitude (Cody 1994, 1996; Cody et al. 1998). The site reported above is intermediate between these areas.

CORNACEAE

Cornus stolonifera Michx., Red-osier Dogwood — YUKON: river cliff, Bonnet Plume River, 65°33'N 134°54'W, *S.C. Zoltai s.n.*, 7 July 1972 (CAFB, photo DAO); dry till with *Populus balsamifera*, 65°50'N 134°51'W, *S.C. Zoltai s.n.*, 10 July 1972 (CAFB, photo DAO).

The specimens cited above are the northernmost yet known in the Yukon Territory. They are an extension of the known range northward of about 240 kilometers from just south of latitude 64°N (Cody 1966).

PYROLACEAE

Chimaphila umbellata (L.) Bart. ssp. *occidentalis* (Rydb.) Hultén, Prince's Pine or Pipsissewa — YUKON: mature *Populus tremuloides* — portage around rapids, Beaver River Lower Rapids, 60°04'51"N 124°52'13"W, *B. Bennett* 97-593, 19 Aug. 1997 (DAO).

Cody (1996) gave a description and illustration of this species and suggested that it should be looked for in southwestern Yukon Territory. The specimen

cited above is however from the extreme southeast of the Territory. It should be added to the list of rare plants of the Yukon (Douglas et al. 1981).

Pyrola asarifolia Michx., Pink-flowered Wintergreen — YUKON: grassy meadow at edge of slough, river floodplain, North Fork of the Fishing Branch River, 66°33'08"N 139°17'48"W, *J. Staniforth* 97-54, 29 Aug. 1997 (DAO).

Cody (1994, 1996) knew this species in northern Yukon Territory north of the Ogilvie Mountains only from a single site adjacent to the Firth River not far from the Arctic Coast. The specimen cited above was collected about 175 kilometers north of the Ogilvie Mountain location and about 310 kilometers south of the Firth River location.

ERICACEAE

Cassiope tetragona (L.) D. Don ssp. *saximontana* (Small) A. E. Porsild — YUKON: windblown ridge, submesic, Kotaneelee Range, 60°13'08"N 124°06'36"W, *B. Bennett* 98-050, 20 June 1998 (*B. Bennett* Herbarium, photo DAO).

Cody (1996) knew this species in the Yukon Territory only about as far east as longitude 129°30'W. The specimen cited above is an extension of the known range of about 350 kilometers to the extreme southeast.

Harrimanella stelleriana (Pallas) Coville, *Cassiope stelleriana* (Pallas) DC., Alaskan Mountain-heather — YUKON: subalpine, Cassiar Mountains, Dorsey Range, 60°08'28"N 131°14'20"W, *C. J. Keddy* 98-A-1, 31 July 1998 (DAO); dwarf shrub dominated by *Luetkea pectinata*, Cassiar Mountains, Dorsey Range, 60°08'21"N 131°14'05"W, *C. Zoladeski* 98-21-2, 31 July 1998 (DAO).

Douglas et al. (1981) knew this rare species in the Yukon Territory only from Kluane National Park and the Cassiar Mountains. The specimens cited above from the Cassiar Mountains were collected about 40 kilometers east of the site known to Douglas et al. (1981).

Kalmia polifolia Wang., Bog-laurel — YUKON: on small palsa, 67°04'N 137°23'W, *S.C. Zoltai s.n.*, 24 July 1972 (CAFB, photo DAO); moist draw just below alpine ridge, Beavercrow Ridge, 60°14'N 124°32'W, *B. Bennett* 98-368, 15 Aug. 1998 (DAO).

The first specimen cited above is the northernmost yet reported in the Yukon Territory and is an extension of the known range about 280 kilometers west-northwest from a site in the Wernecke Mountains near Hart lake [64°36'N 135°09'W] mapped by Cody (1996). The second specimen is an extension of the known range of about 275 kilometers east-southeast of a site in the vicinity of Francis Lake mapped by Cody (1996).

Loisleuria procumbens (L.) Desv., Alpine Azalea — YUKON: moist draw just below alpine ridge,

Beavercrow Ridge, 60°14'N 124°32'W, *B. Bennett* 98-380, 15 Aug. 1998 (DAO).

Cody et al. (1998) extended the known range in the Yukon Territory (Cody 1996) southeastward about 350 kilometers. The specimen cited above is a further extension of the known range about 200 kilometers to the east.

Vaccinium ovalifolium J. E. Smith, Oval-leaved Blueberry — YUKON: subalpine amongst *Abies lasiocarpa*, Beavercrow Ridge, 60°14'N 124°32'W, *B. Bennett* 98-378, 15 Aug. 1998 (DAO); subalpine, Dorsey Range, 60°08'28"N 131°14'20"W, *C.J. Keddy* 98-A-5, 31 July 1998 (DAO); open fir forest, 7 km SE of Ragged Peak, 61°21'57"N 131°27'19"W, *C. J. Keddy* 98-57-4, 9 Aug. 1998 (DAO); 6 km SE of Mt. Hogg, Pelly Mts., 61°17'21"N 132°12'13"W, *C.J. Keddy* 98-49-2, 7 Aug. 1998 (DAO); dry mixed subalpine meadow, upper end of small valley, 1 km NE of Mt. Hogg, Pelly Mts., 61°20'04"N 134°13'15"W, *C. Zoladeski* 98-54-3, 7 Aug. 1998 (DAO); open canopy forest, 7 km SE of McNeil Lake, 61°16'17"N 131°49'32"W, *C. Zoladeski* 98-59-2, 8 Aug. 1998 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). Cody et al. (1998) extended the known range to Mt. Pike, north of latitude 62°N. The first specimen cited above is an extension of the known range in the Territory of about 300 kilometers southeast from the vicinity of Francis Lake. The remaining specimens are from the area surrounded by the Canol Road and the Campbell and Alaska highways.

PRIMULACEAE

Douglasia arctica Hook. — YUKON: alpine tundra, spotty occurrence in raised rocky mounds, mountain between Kusawa and JoJo Lake, 60°35'47"N 136°15'19"W, *B. Bennett* 97-680 and 97-681, 19 Sept. 1997 (DAO).

This species is frequent in northeastern Yukon Territory south to about latitude 65°20'N. The specimen cited above is an extension of the known range in the Territory of about 575 kilometers southward. To the west in southeastern Alaska it does however occur nearly this far south (Hultén 1968).

Primula nutans Georgi — YUKON: Wolf Lake north end near mouth of Wolf River, 60°35'00"N 131°41'30"W, *Mulder & Marion s.n.*, 9 June 1998 (B. Bennett Herbarium, photo DAO).

This amphiberian species was only known to Cody (1996) in the Yukon Territory between longitudes 135°W and 138°W. The specimen cited above is an extension of the known range in the Territory of about 200 kilometers to the east.

GENTIANACEAE

Gentiana prostrata Haenke, Moss Gentian — YUKON: windblown ridge, submesic rocky, uncom-

mon, Kotaneelee Ridge, 60°13'08"N 124°06'36"W, *B. Bennett* 98-041, 20 June 1998 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 375 kilometers east of a site north of the Alaska Highway west of longitude 130°W mapped by Cody (1996).

APOCYNACEAE

Apocynum androsaemifolium L., Spreading Dogbane — YUKON: dry steep hillside adjacent to warm springs, Beaver River Hotsprings, 60°22'53"N 125°34'33"W, *B. Bennett* 97-598, 15 Aug. 1997 (DAO).

The specimen cited above is an extension of the known range in southeastern Yukon Territory of about 100 kilometers east of a site mapped by Cody (1996).

POLEMONIACEAE

Polemonium boreale Adams, Northern Jacob's-ladder — YUKON: high subalpine scree, large talus, Kotaneelee Range, 60°14'43"N 124°17'50"W, *B. Bennett* 98-347, 19 June 1998 (DAO).

Cody (1996) knew this species in the Yukon Territory only west of longitude 134°W. The specimen cited above is an extension of the known range in the Territory of about 600 kilometers east of a site south of Carcross.

BORAGINACEAE

Asperugo procumbens L., Madwort — YUKON: along fence around garden, Whitehorse, *Gillett & Mitchell* 3509, 23 June 1949 (DAO).

Boivin (1966) reported the occurrence of this introduced species in the Yukon Territory but unfortunately it was overlooked during the writing of Flora of the Yukon Territory. It has not been found again in the Territory since 1949. *Asperugo* can be differentiated from other Boraginaceae genera in the Yukon by its leafy bracted lower flowers, the fruiting calyx greatly enlarged and strongly veined, with 5 broad, flat lobes and having the stem retrorsely prickly-hispid.

Myosotis alpestris Schm. ssp. *asiatica* Vestergr., Mountain Forget-me-not — YUKON: windblown ridge, submesic rocky, Kotaneelee Range, 60°13'08"N 124°06'36"W, *B. Bennett* 98-110, 20 June 1998 (DAO).

This is a widespread species in the Yukon Territory which was previously unknown in the southeast corner. The specimen cited above is an extension of about 350 kilometers east and southeast from the nearest sites mapped by Cody (1996).

SCROPHULARIACEAE

Limosella aquatica L., Water Mudwort — YUKON: with *Ranunculus gmelinii*, *Caltha natans* and *Alopecurus aequalis*, Old Crow Flats, 68°01'N 140°33'W, *N. Hughes s.n.*, 27 July 1997 (B. Bennett Herbarium, photo DAO).

Douglas et al. (1981) knew this rare plant in the Yukon Territory from a single collection adjacent to the Upper Canol Road (Cody 1994). Cody (1994) and Cody et al. (1998) added additional sites at the Nisutlin River Delta and the Liard River south of Watson Lake. The specimen cited above extends the known range in the Territory almost 800 kilometers to the northwest from the Canol Road site.

Mimulus guttatus DC., Yellow Monkeyflower — YUKON: wet areas beside beaver pond, La Biche River, 60°04'41"N 124°02'42"W, *B. Bennett* 95-161a, 10 June 1995 (DAO); riverbar, La Biche Camp #2, 60°00'57"N 124°06'00"W, *B. Bennett* 97-360, 14 June 1997 (DAO).

Cody (1996) knew this species which was considered rare in the Yukon Territory (Douglas et al. 1981) only as far east as about longitude 125°15'W. The specimens cited above extend the known range in the Territory eastward about 100 kilometers.

Rhinanthus minor L. ssp. *borealis* (Sterneck) A. Löve, Yellow Rattle — YUKON: disturbed meadow in townsite, Hootalinqua, 61°35'N 134°54'W, *B. Bennett* 97-624, 19 July 1997 (DAO); roadside near Upper Gas Well, 60°07'25"N 124°06'02"W, *B. Bennett* 97-206, 23 June 1997 (DAO).

This species, although it is not common in the Yukon Territory, was not included in the Rare Plants of the Yukon Territory (Douglas et al. 1981) because it is widespread. The Hootalinqua collection which is about 75 kilometers northeast of a location adjacent to the Klondike Highway (Cody 1996) is the northernmost yet found in the Territory and the Upper Gas Well site is an extension of the known range in the Territory of about 470 kilometers from a site mapped by Cody (1996) adjacent to Teslin Lake.

Veronica peregrina L. ssp. *xalapensis* (H.B.K.) Pennell, Neckweed — YUKON: wet ditch beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, *B. Bennett* 97-157, 27 June 1997 (DAO).

Cody (1996) knew this species in the Yukon Territory only from the vicinities of Dawson and Whitehorse and suggested that it was probably introduced in the Territory.

LENTIBULARIACEAE

Utricularia minor L., Lesser Bladderwort — YUKON: La Biche River area, 60°03'N 124°00'W, *B. Bennett* 97-649, 25 June 1997 (DAO).

This species, although it is not known to be common in the Yukon Territory, was not included in the Rare Plants of the Yukon Territory (Douglas et al. 1981) because it is widespread. The specimen cited above is an eastward extension of the known range in the Territory of about 250 kilometers from the easternmost location known to Cody (1996).

Utricularia vulgaris L. ssp. *macrorrhiza* (LeConte) Clausen, Greater Bladderwort — YUKON: floating on

surface of pond, Lee's Camp, Beaver River, 60°11'57"N 125°09'42"W, *B. Bennett* 97-478, 18 Aug. 1997 (DAO); floating in water, Richardson Mountains, 67°07'N 137°13'W, *S.C. Zoltai s.n.*, 28 July 1972 (CAFB, photo DAO).

The first specimen cited above is an extension of the known range in the Yukon Territory of about 350 kilometers from a site plotted by Cody (1996) adjacent to the southern Canol Road. In the north there are only two known locations of this species north of the second site cited above: Noho Lake 67°52.51'N 139°10.77'W and 68°12'N 139°48'W (Cody 1996). To the south of the second specimen the nearest location is at Mile 90 Dempster Highway, a distance of about 240 kilometers.

CAMPANULACEAE

Campanula lasiocarpa Cham., Mountain Hairbell — YUKON: alpine meadow, exposed rock on edge, Beavercrew Ridge, 60°14'N 124°35'W, *B. Bennett* 98-322, 15 Aug. 1998 (DAO).

The specimen cited above extends the known range in the Yukon Territory (Cody 1996) about 75 kilometers eastward from a site adjacent to the Beaver River.

Campanula uniflora L., Arctic Hairbell — YUKON: windblown ridge, submesic rocky, Kotaneelee Range, 60°13'08"N 124°06'36"W, *B. Bennett* 98-035, 20 June 1998 (DAO).

This is a wide-ranging circumpolar species which Cody (1996) knew mainly in the Yukon Territory in the British, Richardson, Ogilvie and St. Elias mountains. The specimen cited above is an extension of the known range in the Territory of about 375 kilometers east of a site mapped by Cody (1996) about longitude 130°33'W.

ASTERACEAE (COMPOSITAE)

Antennaria densifolia A. E. Porsild, Dense-leaved Pussetoes — YUKON: dry graminoid meadow, alluvial outwash plain, upper Fishing Branch River, 66°14'47"N 139°35'31"W, *J. Staniforth* 97-9, 28 Aug. 1997 (DAO).

The specimen cited above is from the most northwesterly site yet found in the Yukon Territory about 115 kilometers from the nearest site adjacent to the Dempster Highway.

Antennaria howellii Greene ssp. *canadensis* (Greene) Bayer — YUKON: pond edge, sedge meadow to dry lake bottom, Buffalo Lake, 61°25'22"N 137°01'44"W, *Staniforth & Rosie* 98-61, 25 Aug. 1998 (DAO); growing on an overgrown portion of the airstrip, Larsen Airstrip, 60°10'35"N 125°03'22"W, *B. Bennett* 98-265, 13 June 1998 (*B. Bennett* Herbarium, photo DAO).

Cody (1996) mapped only a single locality for this subspecies in southern Yukon Territory west of longitude 127°W. A second locality in the vicinity of

Watson Lake was reported by Cody et al. (1998). The specimens cited above extend the known range in the Territory about 475 kilometers to the west and 150 kilometers to the east.

Antennaria monocephala DC. ssp. *monocephala*, One-headed Pussytoes — YUKON: alpine ridge adjacent to subalpine lake, Beavercrow Ridge, 60°11'N 124°35'W, *B. Bennett* 98-507, 16 Aug. 1998 (B. Bennett Herbarium, photo DAO); dry alpine above talus, Beavercrow Ridge, 60°13'N 124°32'W, *B. Bennett* 98-508, 15 Aug. 1998 (B. Bennett Herbarium, photo DAO).

This species is widespread throughout the mountainous regions of the Yukon Territory. The specimens cited above are an extension of the known range in the Territory (Cody 1996) of about 200 kilometers to the extreme southeast from a site west of longitude 127°W.

Arnica angustifolia Vahl in Hornem. ssp. *angustifolia*, Alpine Arnica — YUKON: moist meadow at base of talus near summit, Kotaneelee Range, 60°13'08"N 124°06'36"W, *B. Bennett* 98-161, 20 June 1998 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 300 kilometers to the southeast of the vicinity of Francis Lake.

Arnica chamissonis Less. ssp. *chamissonis*, Meadow Arnica — YUKON: bank of creek, Larsen Hotsprings Lower Pool, 60°12'N 125°32'W, *B. Bennett* 97-361, 20 Aug. 1997 (DAO); in lush Balsam Poplar/*Heracleum* woods near warm springs, Frances Lake, 61°34'N 129°26'W, *R. Rosie* 1955, 19 July 1997 (DAO); riverbar in sand in open, La Biche River, 60°13'58"N 124°13'58"W, *B. Bennett* 98-127, 17 June 1998 (DAO); central delta in sand at edge of channel, just in front of *Salix* border, Nisutlin River Delta, National Wildlife Area, 60°13'11"N 123°31'23"W, *B. Bennett* 98-499, 26 July 1998 (DAO).

Cody (1996) knew this subspecies from only four localities in the Yukon Territory south of latitude 62°N. The first two specimens cited above extend the known range east of longitude 129°W of about 300 kilometers. The third is an extension north of latitude 60°16'N of about 150 kilometers.

Arnica lessingii Greene, Purple Arnica — YUKON: in rock crack on exposed ledge over edge of ridge, Beavercrow Ridge, 60°12'N 124°35'W, *B. Bennett* 98-501, 16 Aug. 1998 (B. Bennett Herbarium, photo DAO).

The specimen cited above is an extension of the known range in the Yukon Territory (Cody 1996) of about 250 kilometers to the east from a site west of Watson Lake.

Arnica lonchophylla Greene — YUKON: alpine tundra, Richardson Mts., 66°12'N 136°07'W, *S.C. Zoltai s.n.*, 15 July 1972 (CAFB, photo DAO).

The specimen cited above is a northeastward extension of the known range in the Yukon Territory of about 280 kilometers (Cody 1996).

Artemisia biennis Willd., Wormwood — YUKON: disturbed area beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, *B. Bennett* 98-497, 14 Aug. 1998 (B. Bennett Herbarium, photo DAO).

Cody (1996) knew this introduced species in the Yukon Territory from the far north adjacent to the Porcupine River.

Artemisia frigida Willd., Prairie Sagewort — YUKON: dry rock outcrop, Beaver River, 60°09'09"N 124°55'16"W, *B. Bennett* 97-544, 19 Aug. 1997 (DAO); dry steep sedimentary slope, Beaver River above lower rapids, 60°01'37"N 124°36'38"W, *B. Bennett* 97-581, 19 Aug. 1997 (DAO).

The easternmost locations of this species known to Cody (1996) were adjacent to the southern Canol Road. The specimens cited above are an extension of the known range in the Yukon Territory of about 475 kilometers.

Aster alpinus L. ssp. *vierhapperi* Onne, Alpine Aster — YUKON: Dry south-facing slope with *Artemisia frigida*, Beaver River Lower Canyon, 60°09'09"N 124°55'16"W, *B. Bennett* 97-537, 19 Aug. 1997 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 150 kilometers eastward from about longitude 127°15'W.

Aster modestus Lindl. in DC., Western Bog Aster — YUKON: adjacent to alpine pond, east of Mt. Dickie, Beavercrow Ridge, 60°13'N 124°34'W, *B. Bennett* 98-569, 16 Aug. 1998 (DAO).

Cody (1996) knew this species which Douglas et al. (1981) considered rare in the Yukon Territory from only three localities in the southeast corner. The specimen cited above is an extension of the known range in the Territory of about 60 kilometers to the east.

Erigeron grandiflorus Hook. ssp. *arcticus* A. E. Porsild, Large-flowered Daisy — YUKON: moist pockets on talus near ridge summit, Kotaneelee Range, 60°13'08"N 124°06'36"W, *B. Bennett* 98-495, 19 June 1998 (B. Bennett Herbarium, photo DAO); dry ridge, Kotaneelee Range, 60°14'31"N 124°17'19"W, *B. Bennett* 085, 20 June 1998 (DAO).

This species was known in the Yukon Territory to Cody (1996) only west of longitude 136°W. The specimens cited above extend the known range in the Territory disjunct to the extreme southeast. It is however known in the southern Mackenzie Mountains in the District of Mackenzie (Porsild and Cody 1980).

Hieracium gracile Hook., Slender Hawkweed — YUKON: alpine ridge, moist draw, Beavercrow

Ridge, 60°13'N 124°32'W, *B. Bennett* 98-506, 15 Aug. 1998 (B. Bennett Herbarium, DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 175 kilometers southeast of a location cited by Cody et al. (1998) on Mt. Skonseng ridge.

Lactuca biennis (Moench.) Fern., Tall Blue Lettuce — YUKON: gravel bar in river by hot springs, Beaver River Hot Springs, 60°22'53"N 125°34'33"W, *B. Bennett* 97-426, 15 Aug. 1997 (DAO).

Previously known in the Yukon Territory from a single collection at the 2nd hot springs on Larsen Creek, 60°12'30"N 125°32'W (Cody 1994, 1996).

Matricaria matricarioides (Less.) Porter, Pineappleweed — YUKON: disturbed soil adjacent to cabin, Larsen Airstrip, 60°07'42"N 124°02'21"W, *B. Bennett* 97-606, 18 Aug. 1997 (DAO).

The specimen cited above is an eastward extension of the known range in the Yukon Territory of about 225 kilometers from adjacent to the Alaska Highway at Contact Creek, longitude 127°44.5'W (Cody 1996).

Matricaria perforata Méral, Scentless Mayweed — YUKON: beside cabin on end of spit, Nisutlin River Delta, National Wildlife Area, Coldwell Bay, 60°14'14"N 132°32'40"W, *B. Bennett* 98-196, 29 July 1998 (DAO).

Cody (1996) knew this introduced species in the Yukon Territory, the vicinity of Ross River and the Francis Lake area. The specimen cited above is an extension of the known range in the Territory of about 200 kilometers south and southwest.

Senecio congestus (R.Br.) DC., Marsh Fleabane — YUKON: wet organic soil, south of Caribou River, 66°10'N 134°18'W, *S.C. Zoltai s.n.*, 2 July 1972 (CAFB, photo DAO).

The collection cited above is from a location just west of the District of Mackenzie border about 200 kilometers eastnortheast of a location on the Dempster Highway and 175 kilometers to a location to the northwest (Cody 1996).

Senecio kjellmanii A.E. Porsild — YUKON: dry alpine meadow above steep talus slope, Beaver Creek Ridge, 60°13'N 124°32'W, *B. Bennett* 98-375, 15 Aug. 1998 (B. Bennett Herbarium, photo DAO).

Cody (1996) knew this species in the Yukon Territory only west of longitude 135°W. The specimen cited above extends the known range in the Territory disjunct to the extreme southeast. It is however known in the southern Mackenzie Mountains in the District of Mackenzie (Porsild & Cody 1980).

Senecio vulgaris L., Common Groundsel — YUKON: Whitehorse, Wolf Creek Subdivision, 60°37'N 134°55'W, *B. Bennett* 98-205, 11 Aug. 1998 (DAO).

The specimen cited above is only the second reported for the Yukon Territory. Cody (1996) knew it only from the vicinity of Dawson.

Sonchus arvensis L. ssp. *uliginosus* (Bieb.) Nyman, Perennial Sow-thistle — YUKON: disturbed area beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, *B. Bennett* 98-496, 14 Aug. 1998 (DAO).

Cody (1996) knew this introduced species in the Yukon Territory only west of longitude 133°W. The specimen cited above is an extension of the known range in the Territory of about 575 kilometers to the east and southeast.

Sonchus oleraceus L., Common Sow-thistle — YUKON: on side of ridge adjacent to hot spring and in surrounding meadows, Beaver River Hot Spring, 60°22'53"N 125°35'33"W, *B. Bennett* 98-334, 14 Aug. 1998.

Cody (1996) suggested that this introduced species from Europe which is widely distributed throughout North America was to be expected in the Yukon Territory.

Taraxacum ceratophorum (Ledeb.) DC. s.l., Horned Dandelion — YUKON: meadow by roadside, Upper Gaswell, 60°07'N 124°06'02"W, *B. Bennett* 97-191, 16 June 1997 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 75 kilometers to the east of longitude 125°15'W.

Taraxacum officinale Weber in Wiggins, Common Dandelion — YUKON: riverside, Lower Beaver River, 60°02'00"N 124°31'40"W, *B. Bennett* 97-203, 9 June 1997 (DAO); meadow by roadside, Upper Gas Well, 60°07'25"N 124°06'02"W, *B. Bennett* 97-194, 16 June 1997 (DAO).

The specimens cited above are an extension of the known range eastward of about 215 kilometers from adjacent to the Alaska Highway at Contact Creek, longitude 127°44.5'W.

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Migration of King, *Somateria spectabilis*, and Common, *S. mollissima v-nigra*, Eiders past Point Barrow, Alaska, during Spring and Summer/Fall 1996

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We counted migrating King (*Somateria spectabilis*) and Common (*S. mollissima v-nigra*) eiders at Point Barrow, Alaska, during spring and summer/fall 1996. During spring (1 May to 2 June), we estimated that 371 451 (95% C.I. \pm 109 093) King and 72 606 (95% C.I. \pm 13 824) Common eiders passed Point Barrow eastbound. During summer/fall (10 July to 16 October), we estimated a passage of 507 667 (95% C.I. \pm 84 680) King and 111 635 (95% C.I. \pm 42 440) Common eiders westbound. Our estimates provide evidence that both populations may have declined since 1976. Many King Eiders were observed in September and October suggesting that 1996 was a productive year. Migration counts during late fall at Point Barrow may provide a means to monitor King Eider production. King Eiders appeared at Point Barrow in early May but the peak of Common Eider migration occurred later. During summer/fall migration, most male and many female King Eiders migrated out of the Beaufort Sea to molt, whereas approximately 75% of the Common Eiders molted before migrating past Point Barrow in September and October. King Eiders comprised 85% to 90% of the identified eider migration. Common Eiders comprised most of the rest, and very small numbers of Spectacled (*Somateria fischeri*) and Steller's eiders (*Polysticta stelleri*) were seen.

Key Words: Beaufort Sea, Common Eider, *Somateria mollissima v-nigra*, King Eider, *Somateria spectabilis*, migration, productivity.

In western North America, King (*Somateria spectabilis*) and Common eiders (*S. mollissima v-nigra*) leave wintering areas in the north Pacific and the Bering Sea and migrate north to nesting areas. At the Bering Strait, the migration divides and some birds move west toward northern Russia and others east to Alaska and northwestern Canada. The eiders moving east follow a series of leads and polynyas in the sea ice through the Chukchi Sea off the west coast of Alaska (Woodby and Divoky 1982). At Point Barrow, Alaska, the migration passes very close to shore and the passage can be spectacular at times, with flocks of eiders appearing to fill the sky. In 1976, Woodby and Divoky (1982) estimated that 113 000 eiders passed in 30 minutes. Various authors have noted the spring passage of eiders at Point Barrow (Murdoch 1885; Bailey 1948; Brueggeman 1980) but the magnitude of the spring migration has been estimated on only a few occasions (Woodby and Divoky 1982; Suydam et al. 1997).

Molt migration for both species begins in early July and fall migration is mostly complete by October (Cotter et al. 1997; Suydam et al. 1997), although some flocks pass as late as November or December (Bent 1925; Bailey et al. 1933; Barry

1986). The westward migration is along a corridor paralleling the north coast of the Yukon Territory and Alaska (Divoky 1984*). At Point Barrow, the migration corridor again passes close to shore as birds leave the Beaufort Sea and fly southwest across the Chukchi Sea (Bailey 1948; Divoky 1984*). The molt and fall migration has been estimated several times (Thompson and Person 1963; Johnson 1971; Suydam et al. 1997).

The primary purpose of this study was to examine population trends of King and Common eiders nesting adjacent to the Beaufort Sea. Those results are presented elsewhere (Suydam et al. 2000). In this paper we: (1) present estimates of the numbers of King and Common eiders passing Point Barrow during the spring and summer/fall of 1996, (2) examine timing of migrations by males and females, and (3) present data on species composition.

Methods

In late April, we established an observation site on the shore-fast sea ice approximately 10 km southwest of Point Barrow (71° 20.5' N, 156° 44' W). The observation site was situated on a block of ice approximately 5 m high and within 100 m of open

water. The site afforded a view of eiders migrating along the nearshore lead edge as well as along the beach approximately 2.5 km to the east. For safety, we switched to a second site on 8 May, approximately 200 m from the lead edge and the first site. We began counting migrating eiders on 1 May and continued until 2 June. Two to four observers counted eiders for up to twelve hours a day (i.e. two hours out of every four) during the 24 hours of daylight in the Arctic spring and summer (Figure 1). On some occasions (33 of the two-hour-counts periods), counts could not be conducted because of unsafe ice conditions or dense fog. We counted for a total of 330 hours (165 two-hour count periods) during spring migration.

During summer and fall, we observed migrating eiders from the base of the Point Barrow spit (71°21' N, 156° 36' W). One to three observers counted eiders for up to 10 hours a day, spread throughout the day, from 10 July to 16 October (Figure 2). During

July and August, we usually counted for about 8 hours a day, but later the shortening day length limited observation time. In October, we were able to count for only two hours a day. We counted for a total of 406 hours during summer/fall migration.

We generally used the same methods to collect and analyze data as described by Suydam et al. (1997). For each counting period we collected data on weather (i.e., cloud cover, fog, precipitation, etc.), temperature, visibility, wind speed and direction. For each flock sighted, we recorded time, direction of travel, species composition, number sighted, ratio of males to females for each species, and other pertinent comments (e.g. interesting behavioral observations of migrating birds). We calculated point estimates for the total passage of King and Common eiders in a manner similar to how Suydam et al. (1997) calculated estimates for 1994, but confidence intervals were calculated differently. Eider migration is greatly influenced by weather conditions and the

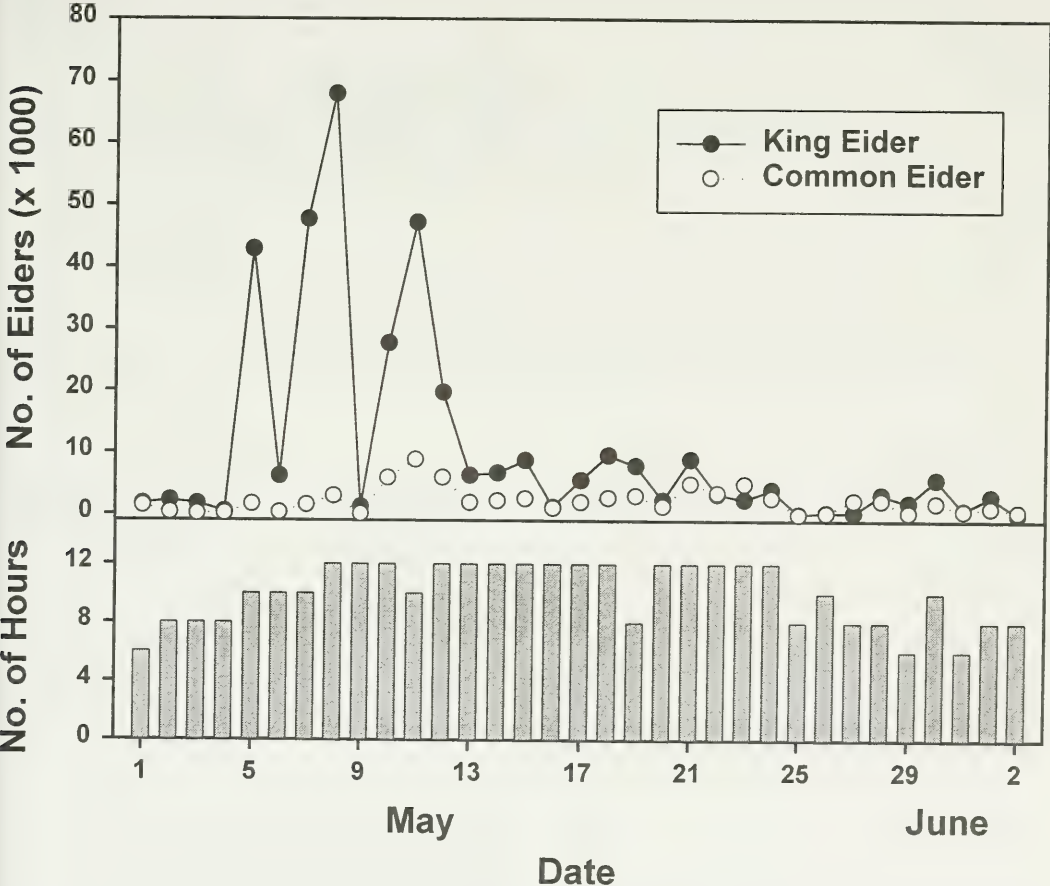


FIGURE 1. Number of hours of observation per day and projected daily passage of King and Common eiders during spring 1996 at Point Barrow, Alaska. Projected passages include unidentified eiders that were divided between King and Common eiders in proportion to King and Common eiders that were identified.

magnitude of the passage is quite variable from day to day (Thompson and Person 1963; Johnson 1971; Timson 1976*; Woodby and Divoky 1982). To estimate variation more accurately, we calculated confidence intervals using a procedure for stratified sampling (Thompson 1992) and designated each day as a stratum. To examine sex ratios, we counted the number of males and females in each flock whenever possible; at other times we estimated the percentage of males in each flock.

Results

Spring Migration

We estimated a total of 371 451 King Eiders passed Point Barrow between 1 May and 2 June (Table 1). King Eiders were seen on the first day of observations in the spring. Some eiders migrated past Point Barrow before we began counting, but we judged that few birds passed using comments from Alaska Native hunters who were camped on the sea ice in late April (C. D. N. Brower, Barrow, Alaska, personal communication). Most King Eiders passed Point Barrow between 5 and 12 May (Figure 1). Our peak count occurred on 8 May when an estimated 70 000 King Eiders passed. Approximately 80% of the King Eiders had passed by 15 May. The percentage of male King Eiders varied from 46% to 92% per day (mean = 56%, SE = 1%; Figure 3). The sex ratio over the entire migration was skewed toward males (56% males; $\chi^2_1 = 1088$, $P < 0.001$).

We estimated that 72 606 Common Eiders passed Point Barrow between 1 May and 2 June (Table 1). The highest number of migrating Common Eiders (approximately 9000 birds) occurred on 11 May, but their numbers varied relatively little throughout May (Figure 1). Approximately 46% of Common Eiders

had passed by 15 May. The percentage of male Common Eiders varied from 50% to 73% per day (mean = 57%, SE = 2%) throughout the migration (Figure 3). The sex ratio over the entire migration was skewed toward males (57% males; $\chi^2_1 = 266$, $P < 0.001$).

King Eiders comprised 85% of all the eiders we identified migrating past Point Barrow during spring 1996. Common Eiders made up slightly less than 15% of the eider migration, and we also observed 31 Spectacled Eiders (*S. fischeri*) and 10 Steller's Eiders (*Polysticta stelleri*).

Summer/Fall Migration

We estimated a total of 507 667 King Eiders passed Point Barrow between 10 July and 16 October (Table 1). Molt migration began before our first day of counts, but it is unlikely that many eiders passed before 10 July based on our observations and those of Alaska Native hunters (C. D. N. Brower, Barrow, Alaska, personal communication). King Eiders passed in large numbers on 20 to 22 July, 29 July, 20 and 29 August, and 13 to 26 September (Figure 2). Approximately 63% of the King Eiders had passed Point Barrow by 1 September. We observed 37 633 King Eiders closely enough to estimate the sex ratio. From 10 July to 5 August, 82% to 99% of the King Eiders were males (Figure 4). After 5 August, the sex ratio began to shift, becoming mostly females by 19 August (Figure 4). From 10 July to 1 September the percentage of adult males varied from 0% to 100% (mean = 63%, SE = 6%). After 1 September, our estimates of males are low because we could not distinguish females from juvenile males.

We estimated a total of 111 635 Common Eiders passed Point Barrow between 10 July and 16

TABLE 1. Numbers of King, Common and unidentified eiders seen during the spring and summer/fall migrations in 1996, projected total passage, and 95% confidence interval.

	King Eider	Common Eider	Eider ¹	TOTAL
<i>Spring</i> ²				
Number Seen ³	87 663	15 401	81 717	182 781
Projected Total Passage ⁴	371 451	72 606		444 057
95% Confidence Interval	±109 093	±13 824		
Coefficient of Variation	0.136	0.088		
<i>Summer/Fall</i> ⁵				
Number Seen ³	51 981	5 893	86 517	144 391
Projected Total Passage ⁴	507 667	111 635		619 302
95% Confidence Interval	±84 680	±42 440		
Coefficient of Variation	0.076	0.173		

¹Unidentified eiders.

²From 1 May to 2 June.

³Net number of birds migrating northeast (spring) or southwest (summer/fall).

⁴Sum of the daily projected passage — number seen expanded for the time not observed. Unidentified eiders were divided between King and Common eiders for each day based on the proportion of King and Common eiders observed for that day.

⁵From 10 July to 16 October.

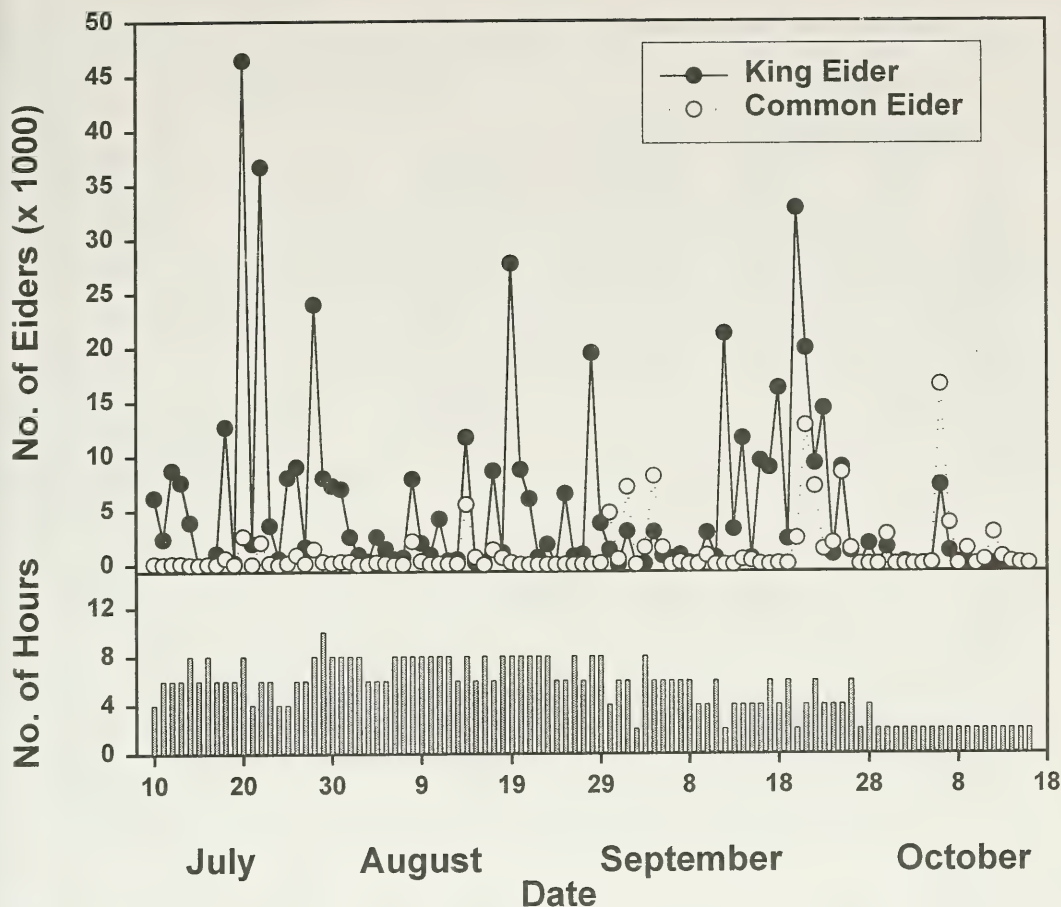


Figure 2. Number of hours of observation per day and projected daily passage of King and Common eiders during summer/fall 1996 at Point Barrow, Alaska. Projected passages include unidentified eiders that were divided between King and Common eiders in proportion to King and Common eiders that were identified.

October (Table 1). There were relatively few large pulses of Common Eiders between 10 July and 30 August (Figure 2). Several large pulses occurred between 30 August and 5 September, between 21 and 26 September and on 7 October (Figure 4). Approximately 24% of the Common Eiders passed by 1 September and 76% had passed by 1 October. We observed 4841 Common Eiders closely enough to estimate the sex ratio. The percentage of male Common Eiders passing per day between 10 July and 19 August was highly variable (0 to 100%), but consisted mostly of males (mean = 87%, SE = 3%; Figure 4). After 19 August, the flocks changed to mostly females and juveniles until 23 September when the number of adult males again increased (Figure 4). Over the entire summer/fall migration, 67% (SE = 5%) of the Common Eiders were adult males.

King Eiders comprised 90% of all the eiders we

identified migrating past Point Barrow during summer/fall 1996. Common Eiders made up a little less than 10% of the eider migration, and we also observed 42 Spectacled Eiders and 3 Steller's Eiders.

Discussion

Numbers of Eiders

Our estimate of the number of King Eiders passing Point Barrow during spring 1996 was similar to 1994 estimates (Suydam et al. 1997). Our summer/fall estimate, however, appears to be different even though confidence intervals overlapped. We observed a large number of eiders in September and October (113 000) whereas few were observed during the same time period in 1994 (13 000; Suydam et al. 1997). Summer/fall migration includes juveniles after late August or early September (Timson 1976*). In 1996, productivity was high for Beaufort Sea King Eiders that nested in the Queen Maud Gulf

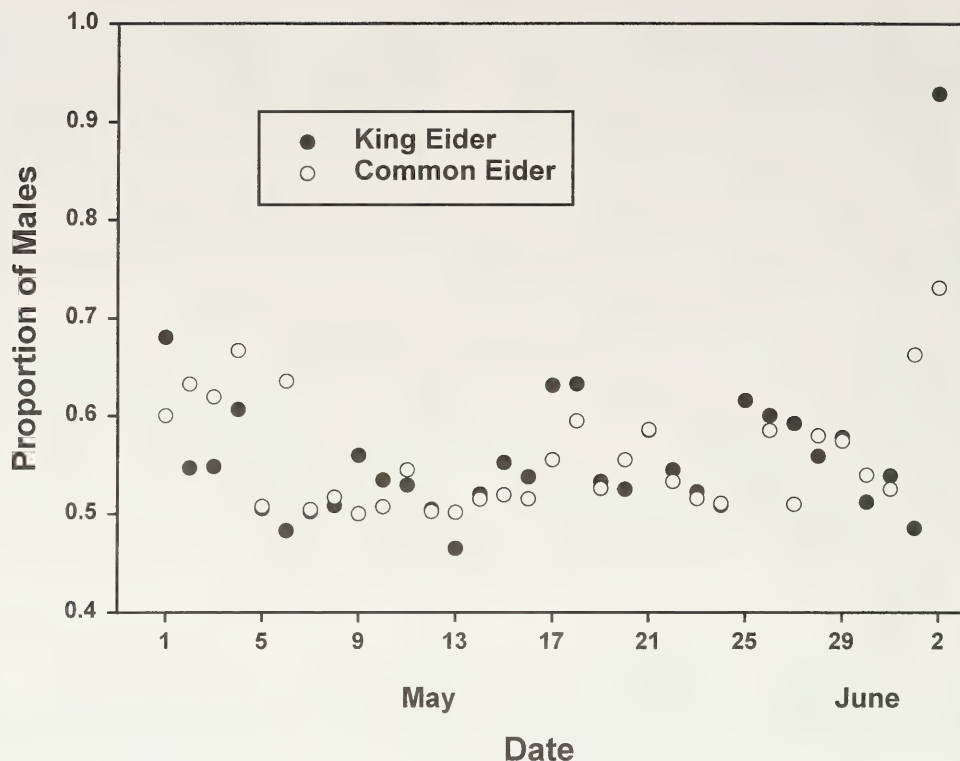


Figure 3. Percentage of males observed in eider flocks during the spring migration at Point Barrow, Alaska, 1996. On 2 June, skewed sex ratio of King Eiders is because only 14 birds were seen. Percentages are given for only days when we observed at least 10 King or Common eiders.

region (Kellett and Alisauskas 1997*). Productivity in the western Canadian Arctic was likely high as well; spring break-up was early, the birds arrived in superior body condition (Byers 1998*) and lemming numbers were extremely high throughout the region (R. Bromley, Yellowknife, NWT, personal communication). In years when small Arctic mammals are experiencing population highs, predators, especially Arctic Foxes (*Alopex lagopus*), take fewer eggs or chicks, resulting in higher breeding success of ground-nesting birds (Larson 1960; Ebbinge 1989; Dickson 1992). There are few data on productivity of King Eiders in 1994, but lemming numbers then were extremely low (R. Bromley, Yellowknife, NWT, personal communication); therefore, predation on King Eiders was probably high. Although we did not differentiate between adult females and juveniles during migration, we suspect that many eiders that passed in September and October in 1996 were juveniles. Many females leave brood-rearing areas before their young are ready to migrate, although some successfully breeding females migrate with their young (Palmer 1976). Fall migration counts during September and October at Point Barrow may be a useful way to monitor productivity of King

Eiders if adult females can be separated from juveniles. One possibility is through hunter bag checks.

The estimates of King Eiders from 1994 and 1996 are approximately 55% less than the estimates from 1953, 1970, and 1976 (Thompson and Person 1963; Johnson 1971; Woodby and Divoky 1982; respectively). The population of King Eiders from the Beaufort Sea seems to have declined (Suydam et al. 2000).

Our estimates of numbers of Common Eiders during 1996 were similar to 1994 estimates (Suydam et al. 1997). No applicable data are available on breeding success of Common Eiders in 1994 or 1996, and we were not able to assess productivity of Common Eiders from migration counts. Our point estimate for the summer/fall passage of Common Eiders was greater than the spring passage, but large confidence intervals precluded us from using differences in point estimates for assessing productivity for Common Eiders in 1996. Comparing 1996 summer/fall migration with 1994 migration is difficult because so many adult Common Eiders remain in the Beaufort Sea to molt.

Comparisons of recent summer/fall estimates of Common Eider numbers with previous estimates are

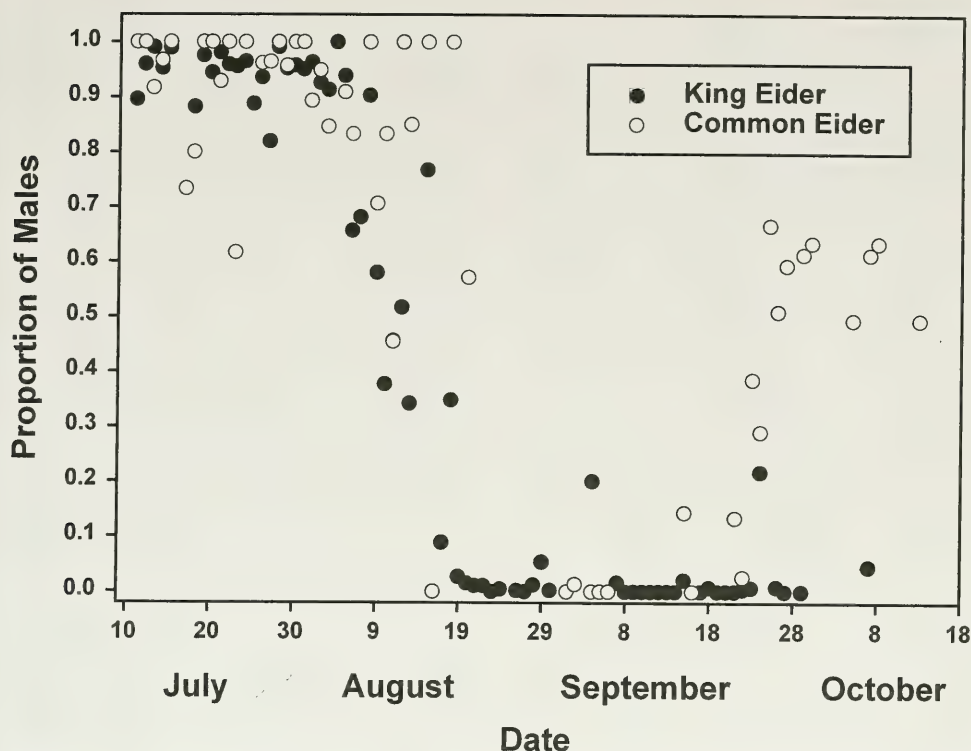


Figure 4. Percentage of males observed in eider flocks during the summer/fall migration at Point Barrow, Alaska, 1996. After 1 September, the percentages of males are minimal because of the difficulty in differentiating between females and juvenile males in flight. Percentages are given for only days when we observed at least 10 King or Common eiders.

difficult (Suydam et al. 2000). We could not compare our summer/fall estimates with the earlier counts conducted by Thompson and Person (1963), Johnson (1971) and Timson (1976*) because their counts ended four to 12 weeks before the end of Common Eider migration. Common Eider numbers from spring counts in 1994 and 1996 were approximately 55% less than that of the 1976 spring estimate (Woodby and Divoky 1982). Recent estimates of numbers of Common Eiders suggest that they have declined (Suydam et al. 2000).

Timing of Migration

The peak movement of King Eiders past Point Barrow during spring migration tends to occur before that of Common Eiders (Woodby and Divoky 1982; Suydam et al. 1997). In 1996, the tendency was the same but less pronounced than in other years. The bulk of the King Eider migration occurred in early May in several large pulses (Figure 1), whereas Common Eider migration was more evenly spaced throughout May (Figure 2). Why King Eiders migrate before Common Eiders is not clear. King Eiders nest primarily on Banks and Victoria islands

(Barry 1986; Dickson et al. 1997), whereas Common Eiders tend to migrate farther to the east (Cornish and Dickson 1997). Thus, early passage of King Eiders at Point Barrow is not due to a need to migrate farther.

Woodby and Divoky (1982) observed that male King Eiders migrated past Point Barrow before females. They suggested that King Eiders migrated earlier than other species so that pair formation could occur at staging areas in the Beaufort Sea. In 1994 (Suydam et al. 1997) and in 1996 (this study), however, most King Eiders were paired when they passed Point Barrow. If 1976 was more typical of King Eider migration than 1994 or 1996, differences in timing of pair formation might explain differences in migration timing.

A more likely explanation of the differences in migration timing between King and Common eiders might be due to differences in nesting habitats. King Eiders typically nest in low density across the tundra and initiate nests earlier than Common Eiders (Palmer 1976; Cramp and Simmons 1977). The main spring staging areas for King Eiders are in open leads in the southeast Beaufort Sea between Cape

Dalhousie and the Baillie Islands and off western Banks Island (Barry 1986; Alexander et al. 1997). The amount of time King Eiders spend at staging areas is dependent on timing of the spring thaw (Barry 1986). Because the summer nesting season is so short in the Arctic, King Eiders move to nesting areas as soon as the snow melts. Common Eiders nest mainly on small marine islands (Cramp and Simmons 1977; Cornish and Dickson 1997). The islands become snow-free long before sea-ice melts. Common Eiders may benefit by waiting for melted sea-ice to form a moat around islands, which would limit access and predation by Arctic Foxes (Larson 1960; Barry 1986).

In 1996, timing of spring migration for King Eiders was somewhat earlier than during other migrations. In 1976, the majority of King Eiders passed after 25 May (Woodby and Divoky 1982), and in 1987 only 50% had passed before 15 May (Suydam et al. 1997). In 1994, the majority of the passage occurred between 10 and 20 May (Suydam et al. 1997). Murdoch (1885) described the King Eider migration in spring at Point Barrow as occurring mainly in several periods with high passage rates. Woodby and Divoky (1982) suggested that King Eiders migrate with the first favorable wind conditions in the spring. Migrating too early, however, can increase the risk of mortality. Barry (1968) estimated 100 000 King Eiders died due to starvation in severe ice conditions in the Beaufort Sea in 1964. Other years of starvation have also been recorded (Fournier and Hines 1994). Favorable wind conditions in 1996 may explain the relatively early migration. Only two days of head winds (as defined by Thompson and Person 1963) occurred between 1 May and 2 June; the remaining days had favorable or neutral wind conditions (National Oceanic and Atmospheric Administration, National Weather Service, Barrow, Alaska). In contrast, head winds occurred for 24 days during May 1994 with only three days of tail winds (National Oceanic and Atmospheric Administration, National Weather Service, Barrow, Alaska). Strong and persistent head winds in spring 1976 caused the peak of migration to occur in late May (Woodby and Divoky 1982).

Movements of male King Eiders during fall 1996 were similar to 1994, the only other fall migration count that extended into October. Most adult males passed Point Barrow by 19 August with only a small number observed after that date (Figure 4; Suydam et al. 1997). Males leave nesting areas shortly after females begin incubation (Lamothe 1973; Palmer 1976). They migrate to molting areas presumed to be located in northwest Alaska (Johnson and Herter 1989) or along the Siberian coast (Salomonsen 1968; Portenko 1972). Kistchinski (1973) provides a description of migration routes, molting areas, and numbers of eiders for the Russian Far East. Female

movements were also similar between 1996 and 1994. Females began appearing in the migration about 1 August and predominated by mid-August (Figure 4; Suydam et al. 1997).

Common Eiders moved past Point Barrow at a steadier rate in spring 1996 than during migrations in 1976, 1987, and 1994, when they migrated in several large pulses (Woodby and Divoky 1982; Suydam et al. 1997). Woodby and Divoky (1982) suggested that the timing of spring migration, during years of mild wind conditions, may be more protracted. This likely occurred with Common Eiders in 1996 because of the favorable and neutral wind conditions. In 1994, Common Eiders mainly migrated past Point Barrow on the days with tail winds (R. Suydam and L. Quakenbush, unpublished data).

Timing of movements of Common Eiders during the fall was similar between 1994 (Suydam et al. 1997) and 1996 (Figure 2). During both years, few Common Eiders passed during July and early August. In 1994, there was a large passage in October (Suydam et al. 1997), whereas in 1996, there were several pulses of birds in September and October (Figure 4). In both 1994 and 1996, migrating adult male Common Eiders were observed in September and October having already completed wing-molt. Our observations suggest many adult male Common Eiders, and presumably adult females, molt their flight feathers before migrating across the Beaufort Sea. Molting locations are largely unknown, although Barry (1986) noted flightless Common Eiders at Cape Parry and Prince of Wales Strait in 1981. Additionally, some birds molt near breeding islands along the Beaufort Sea coast.

Species Composition

The species composition we observed was similar to other eider migration counts near Point Barrow. King Eiders comprised the largest portion of the identified migration, from 80.8% to 95%, and Common Eiders comprised from 5% to 17.3% of the migration (Johnson 1971; Woodby and Divoky 1982; Suydam et al. 1997). Johnson (1971) likely underestimated the number of Common Eiders in the migration because counts ended on 7 September prior to the completion of migration. Timson (1976*) observed 97% King Eiders and 3% Common Eiders, but that count missed the early and late portions of the migration. The species composition of eider migrations at Point Barrow appears to be similar over the past 30 years.

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Arctic Fox, *Alopex lagopus*, Den Densities in the Prudhoe Bay Oil Field, Alaska

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Studies conducted in the Prudhoe Bay, Alaska area since the 1970s suggested that Arctic Fox (*Alopex lagopus*) populations may have increased as a result of oil field development. During 1993, we estimated fox den densities within the Prudhoe Bay area and compared our estimates with those made previously in the same area and from other Arctic areas. The number of natal fox dens was stable between 1992 ($n = 25$) and 1993 ($n = 26$), as was mean litter size (4.6 and 4.4 pups per litter in 1992 and 1993, respectively). Fox den density was greater (1/15.2 km²) within developed areas than on adjacent undeveloped tundra (1/28.1 km²), and foxes used culverts and road embankments as den sites in addition to natural dens. Densities of fox dens in Prudhoe Bay development area and adjacent tundra were within the range of density estimates found in other Arctic areas.

Key Words: *Alopex lagopus*, Arctic Fox, den densities, oil development, Alaska.

Studies conducted since 1970 suggested that oil development in Prudhoe Bay, Alaska had no deleterious effects on Arctic Fox (*Alopex lagopus*) populations (Eberhardt et al. 1982; 1983a, b), and provision of a stable food source may have had some beneficial effects (Bousfield and Syroechkovskiy 1985). Recent work by Burgess et al. (1993*) further supports the contention that an increased, sustained anthropogenic food supply in developed areas may promote and maintain higher fox densities than would be expected in undeveloped areas.

The possibility that artificially high fox populations may lead to (1) abnormally high predation of tundra bird populations, and (2) increased human exposure to rabies, prompted BP Exploration (Alaska) Inc. (BPX) to initiate a study in 1991 of the Arctic Fox in the Prudhoe Bay area (Burgess and Banyas 1993*; Burgess et al. 1993*; Rodrigues et al. 1994*; Robards et al. 1996*). The purpose of our study was to document the densities of Arctic Fox den sites within the Prudhoe Bay Oil Field in 1993 and compare these densities with Arctic Fox populations found in other Arctic areas.

Study Area

The study area included the Prudhoe Bay Oil Field Unit (PBU [805 km²]) and portions of an adjacent undeveloped area (760 km²). The area was bounded

on the north by the Beaufort Sea and the northern boundary of Township 12 North, on the east by the Sagavanirktok River delta, on the west by a line south from Milne Point, and on the south by the southern boundary of Township 9 North (within 147°50'–149°10' N longitude and 70°25'–70°10' W latitude). The area has been described by Pollard et al. (1986a,b).

Methods

Aerial surveys were conducted in May 1993 using fixedwing aircraft (Piper PA18) flying at 50 to 100 m above ground level. Transects were spaced 1.6 km apart and flown in a north-south direction in a grid fashion following U.S. Geologic Survey section lines. A Trimble *Pathfinder* Global Positioning System (GPS) was used to navigate the aircraft and to determine the location of den sites. This time period was selected because snow was still present and fox activities (digging and tracks) at den sites were conspicuous from the air (Garrott 1980; Burgess et al. 1993*). Fox dens were classified as active if there were signs of use, and inactive if there were not.

Aerial surveys were repeated on 13 July 1993 to determine if sites identified in May were active and to attempt to identify additional sites. Determining the status of fox dens in July was more difficult than in May because, although both active and inactive dens were relatively conspicuous due to enhanced growth of vegetation (Chesemore 1969; Garrott 1980; Smits et al. 1988), evidence of recent fox activity was difficult to distinguish from the air.

*See Documents Cited section.

Ground surveys of fox dens accessible from the road system were conducted daily from 29 June to 31 July 1993 to determine the status of each den. Observations were made with binoculars or spotting scopes at all hours of the day and night. Observation time ranged from 10 minutes to 2 hours depending upon whether the observer was confident that all pups had been counted. Dens were considered active if there were signs of current use, such as fresh digging and wellworn trails. Active dens were considered to be natal dens if pups were present, small feces or tracks were present, or by presence of abundant prey item remains (Burgess et al. 1993*). Nonnatal dens, to which pups were moved after whelping, were classified as secondary dens.

Dens were classified as natural or artificial. The status of natural dens was designated as natal, secondary, active nonnatal (i.e., signs of activity by adults only), inactive, or status unknown. The status of artificial dens (i.e., dens associated with manmade structures such as culverts, under trailers, or burrows in gravel road banks) was designated as active or inactive. A number of new dens were located during this process, both natural and artificial. All artificial dens were considered to be secondary dens based upon the relative size of pups.

Results

Fifty-three natural Arctic Fox dens (1 den/15.2 km²) were located in the PBU in 1993 compared to 44 dens (1 den/18.3 km²) in each of the previous two years (Table 1). Natal dens comprised 57% of total number of natural dens in 1992 and 49% in 1993. The status of most dens in 1991 was unknown. Inactive dens comprised 41% and 28% of the total number of natural dens in 1992 and 1993, respectively. For all natural dens, secondary and active nonnatal dens were not identified in 1992, but comprised 15% of the total in 1993.

In the remote portion of the study area, 26 natural fox dens (1 den/29.2 km²) were located in 1993 compared to 25 dens in each of the previous two years (Table 1). The percentage of natal dens was higher in 1992 (54%) than in 1993 (15%). The percentage of inactive dens was higher in 1993 (54%) than in 1992 (38%). The status of most dens was unknown in 1991.

A higher number of artificial dens was found in the PBU in 1993 than in 1992 (Table 1). No artificial dens were identified in 1991. There was no evidence of whelping at artificial dens and none were considered to be natal dens. Three artificial dens located in 1992 were known to be active in 1993, and 16 new artificial dens were located in 1993.

For the entire study area in 1993, at least one fox pup was observed at 23 of the 30 natural dens classified as natal. Mean litter size at these 23 dens was 4.4 pups. These counts must be considered minimum estimates of litter size because of the difficulties in obtaining complete counts as pointed out by Eberhardt (1977), Fine (1980), and Burgess et al. (1993*). Bear (*Ursus arctos*) predation was suspected at two natal dens, and there were signs of bear activity at two other dens.

Discussion

Eberhardt et al. (1983a) reported family occupancy of dens in the Prudhoe Bay Unit to fluctuate between 18% and 74% over a five-year period (1975–79), and 6% to 55% in the Colville River delta (1976–1980). Chesemore (1969) reported that only 2 of 50 dens (4%) in the Teshekpuk Lake region in 1962 had signs of recent use by Arctic Fox pups. Macpherson (1969) reported family occupancy rates of 12 to 40% during four years of study in the Northwest Territories, and Speller (1972) reported rates from 0 to 43% in the same area over a three-year period. Bannikov (1970) reported similar occu-

TABLE 1. Number of Arctic Fox dens located in the Prudhoe Bay Area, Alaska during 1991–1993. Data from 1991 and 1992 from Burgess and Banyas (1993*) and Burgess et al. (1993*).

Den location	Den type	Year		
		1991	1992	1993
Within PBU	Natal	7	25	26
	Secondary			4
	Active Non-natal			4
	Inactive	5	18	15
	Status unknown	32	1	4
	Active Artificial		8	19
	Total	44	52	72
Outside PBU	Natal	3	14	4
	Active non-natal			4
	Inactive	9	14	
	Status unknown	22	2	5
	Total	25	25	27

pancy rates for Arctic Fox dens in Russia. Numbers and percentages of natal dens in the PBU in 1992 (57%) and 1993 (49%), suggested a stable fox population over this two-year period.

The low occupancy rate of dens in the remote portion of the study area in 1993 (15%) compared to 1992 (54%) may be related to lack of ground reconnaissance. Aerial surveys are an efficient and accurate means of locating fox dens (Garrott et al. 1983). However, Garrott (1980) reported that, while occupancy of den sites was easily determined during ground surveys, few reliable determinants of fox activity could be observed during aerial surveys, particularly during June and July.

The density of natural dens in the PBU in 1993 (1 den/15.2 km²) was higher than the density of dens in the remote portion of the study area (1 den/29.2 km²). Some of this difference may be related to intensity of search effort. The road system in the PBU allowed us daily access to that portion of the study area, thus increasing our chances of locating new dens. We also learned of new den locations from conversations with oil field workers and other environmental scientists. Conversely, only two aerial surveys of the remote portion of the study area were conducted during the field season and no new dens were located. The two new dens located in 1993 were near the boundary of the PBU and were the result of ground reconnaissance in the area. Consequently, a much more intensive survey effort was conducted in the PBU.

The density of fox dens for the PBU in the current study (1 den/15.2 km²) was similar to densities reported by other workers for the Prudhoe Bay area. Eberhardt et al. (1983a) reported that the density of fox dens in the Prudhoe Bay area (1 den/12 km²) was approximately three times that of the Colville Delta (1 den/34 km²). They reported a higher percentage of dens of recent origin in the Prudhoe Bay area than in the Colville Delta, and that a dampening of fox population fluctuations which occurred in the Prudhoe Bay area during a year of low lemming (*Lemmus sibiricus*) density was not observed at the Colville Delta. They suggested that garbage in the Prudhoe Bay area provided foxes with an added food supply that accounted for these differences. In Norway, Strand et al. (1999) indicated that increased pup production was associated with years of high rodent abundance, but that adult fox numbers were not associated with rodent abundance. Fine (1980) reported a fox den density of 1 den/15 km² in the PBU, but he suspected that not all dens had been located. The density of fox dens in the PBU was also similar to the density of fox dens reported by Dementyeff (1955) on a 1200 km² study area of the Bolshezemelskaya tundra of Russia (1 den/16 km²).

The density of fox dens in the PBU was also higher than those reported for a number of other areas. Garrott (1980) reported 1 den/42.5 km² on the Colville

Delta, but felt that not all dens in the study area had been located. Urquhart (1973*) reported a density of 1 den/37 km² on Banks Island in the Canadian Arctic, and Macpherson (1969) reported a density of 1 den/36 km² near Aberdeen Lake in the Northwest Territories. Angerbjorn et al. (1991) reported a density of 1 den/22.2 km² for their entire study area in Sweden, although, like us, they found 1 den/16.7 km² in areas where den searches were more intensive.

Higher Arctic Fox den densities than those found at PBU have been reported elsewhere. Anthony et al. (1985) reported a fox den density of 1.03 dens/km² on a 37 km² study area near Kokechik Bay, Alaska. Some Russian studies (cited in Bannikov 1970; Garrott 1980; and Burgess et al. 1993*) have also reported high fox den densities, but Garrott (1980) suggested these densities may have been inflated.

The use of artificial dens by Arctic Fox in the Prudhoe Bay area has been noted by others (Eberhardt 1977; Fine 1980; Eberhardt et al. 1983a; Burgess et al. 1993*), and has been reported in Canada at seismic camps and associated staging areas (Urquhart 1973*). Although more active artificial dens were documented in the PBU in 1993 than 1992, it is difficult to draw conclusions from this. The increase could have been related to search effort.

The litter size of 4.4 pups for the study area in 1993 compares closely with the value of 4.6 pups per litter reported in 1992 by Burgess et al. (1993*). Eberhardt (1977) and Garrott (1980) reported mean litter sizes of 8 and 6.1 pups per family group in their North Slope study areas. During feeding experiments, Angerbjorn et al. (1991) reported litter sizes of 5.2 and 5.7 in experimental and control groups in Sweden. Frafjord (1992) reported litter sizes of 11 to 13 at Arctic Fox dens in Scandinavia, and 4 to 8 in Svalbard. In reviewing Russian literature, Bannikov (1970) stated that Arctic Fox litters averaged 8 to 12 during years of food abundance, but occasionally were as high as 20 to 22. During years of food scarcity the average number of pups per litter was 3 to 5.

The higher density of fox dens, and apparent stability of the fox population in the PBU, may be related to the availability of a stable food source in the form of garbage, refuse, and handouts from oil field workers. However, due to the lack of any predevelopment data on fox den density for the PBU, it is not possible to conclude with certainty that the fox population is currently higher than it was prior to oil field development.

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Status of the Wavy-rayed Lampmussel, *Lampsilis fasciola* (Bivalvia: Unionidae), in Ontario and Canada*

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The Wavy-rayed Lampmussel, *Lampsilis fasciola*, is a medium-sized freshwater mussel that inhabits substrates of gravel and sand in clear, hydrologically stable streams and small rivers. Its most probable fish hosts are the Smallmouth Bass (*Micropterus dolomieu*) and Largemouth Bass (*Micropterus salmoides*). It was once widely distributed (although uncommon) throughout the Ohio and Mississippi drainages and tributaries to the lower Great Lakes, but has declined significantly in recent years. It is listed as endangered in Illinois, threatened in Michigan and New York, and of special concern or interest in Indiana, Ohio and North Carolina. Its range in Canada included western Lake Erie, Lake St. Clair, and the Grand, Thames, Sydenham, Detroit, Ausable and Maitland rivers. Its numbers in Great Lakes waters have been reduced by the Zebra Mussel, *Dreissena polymorpha*, and populations in the Thames, Sydenham and Ausable rivers are disappearing or have been lost primarily as a result of agricultural impacts. The healthiest remaining populations in Ontario are found in a 60 km reach of the upper Grand River, but their future is uncertain because of fishing pressures on their host fish, increasing disturbance from recreational activities such as canoeing, and an anticipated decline in water quality accompanying the rapid rate of human population growth that is projected for the watershed.

Key Words: Unionidae, freshwater mussels, endangered species, COSEWIC, Great Lakes.

The Wavy-rayed Lampmussel, *Lampsilis fasciola*, is a member of the Subfamily Lampsilinae. It was originally described by Rafinesque in 1820. The type locality is given as Ohio by Simpson (1914), and as the Kentucky River by LaRocque (1953). It is readily distinguished from other freshwater mussels by its yellow or yellowish-green rounded shell with numerous thin wavy green rays (Cummings and Mayer 1992). The rays may be narrow and individual or narrow and coalesced into wide rays, but they are always wavy with multiple interruptions. The shell has been described by Clarke (1981) as quadrate-ovate (males) or ovate (females) in shape, heavy and strong, moderately inflated, heavily rayed, and with a mid-anterior shell wall thickness of about 7.5 mm. The surface is smooth except for concentric wrinkles and growth rests, and the posterior ridge is indistinct. The nacre may be white or bluish white. The beaks are elevated, and the beak cavities are moderately excavated; beak sculpture is fine and composed of "...about six concentric broadly curved bars that are sinuous or broken in the centre" (Clarke 1981). Pseudocardinal teeth are triangular, short, thick and divergent, with two teeth in the right valve (anterior tooth small), and two in the left; lateral teeth are short, strong, straight or slightly curved (Clarke 1981; Cummings and Mayer 1992). According to

Strayer and Jirka (1997), the shell is usually less than 75 mm long; however, maximum sizes of 89 mm (Cummings and Mayer 1992), 95 mm (Clarke 1981) and 100 mm (G. T. Watters, Ohio State University, personal communication, June 1998) have been reported. During recent surveys in Canada, the authors have observed specimens up to 91 mm in length. Figure 1 shows a live female and male *L. fasciola* from the Grand River near Kitchener, Ontario.

Distribution

The Wavy-rayed Lampmussel was historically known from New York (Strayer and Jirka 1997), Alabama, Georgia, Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia, West Virginia and Ontario (Williams et al. 1993); see inset, Figure 2A. It was found throughout the Ohio and Mississippi River drainages, as far south as the Tennessee River system (Clarke 1981). In the Great Lakes basin, it occurred in tributaries of Lake Michigan, lower Lake Huron, Lake St. Clair and Lake Erie (Clarke 1981). According to Strayer et al. (1991) and Strayer and Jirka (1997), it also inhabited the Niagara River, tributaries to Lake Ontario, and the upper Allegheny drainage in western New York. In Canada, *L. fasciola* occurred in western Lake Erie, Lake St. Clair, and the Maitland, Sydenham, Thames, Detroit and Grand rivers. It was discovered in the Ausable River, a trib-

*Endangered status assigned by COSEWIC 20 April 1999.



FIGURE 1. Live specimens of *Lampsilis fasciola* found in the Grand River near Kitchener, Ontario in July, 1997. Top specimen is an adult female; bottom specimen is an adult male.

utary to lower Lake Huron, in 1993 (Morris and Di Maio 1998).

Figure 2A depicts the historical distribution of *L. fasciola* in Ontario (and Canada), based on occurrence records (for both live animals and shells) from the National Water Research Institute's Lower Great Lakes Unionid Database. The database and its data sources are described in detail in Metcalfe-Smith et al. (1998a). At present, the database consists of over 5000 records for 40 species of mussels collected from the Canadian waters of the lower Great Lakes drainage basin between 1860 and 1998. A total of 22 historical (pre-1997) records for *L. fasciola* were available from the holdings of the Canadian Museum of Nature (CMN), Ohio State University Museum of Biological Diversity (OSUM), Royal Ontario Museum (ROM) and University of Michigan Museum of Zoology (UMMZ); the private collections of Herbert D. Athearn, Emeritus, Tennessee Academy of Science; Mackie (1996*); and Morris and Di Maio (1998).

Protection

Canada does not have federal endangered species legislation at this time. However, Ontario is one of five provinces that have stand-alone Endangered Species Acts (B. T. Fowler, Chair, Lepidoptera and Mollusca Subcommittee, COSEWIC, personal communication, September 1999). Species classified as provincially Endangered and their habitats are protected from willful destruction under these acts, but

there is currently no protection for provincially Threatened or Vulnerable species. The Provincial Policy Statement under Section 3 of Ontario's Planning Act prohibits development and site alteration in the habitats of provincially Threatened and Endangered Species. The Wavy-rayed Lampmussel is currently being considered for either Endangered or Threatened status by the Committee On the Status of Species At Risk in Ontario (COSSARO). Other mechanisms for protecting mussel habitat in Ontario include the Ontario Lakes and Rivers Improvement Act, which prohibits the impoundment or diversion of a watercourse if it would cause siltation; and the voluntary Land Stewardship II program of the Ontario Ministry of Agriculture, Food and Rural Affairs, which is designed to reduce the erosion of agricultural lands.

Stream-side development in Ontario is managed through flood plain regulations enforced by local conservation authorities. Most land along the reaches of the Grand, Thames, and Maitland rivers where *L. fasciola* was recently found alive is privately owned. Protected areas along the Grand River are too small to have any significance for the protection of this species (Peter Mason, Grand River Conservation Authority, personal communication, March 1998). The Nature Conservancy Canada does not own any property on the Grand or Thames rivers (James Duncan, TNCC, personal communication, March 1998). *Lampsilis fasciola* may still occur in the Sydenham and/or Ausable rivers, as fresh shells were found in both systems. Mosa Township owns 20 ha of forest along the reach of the Sydenham River where shells were found in 1997 (Muriel

*See Documents Cited section.

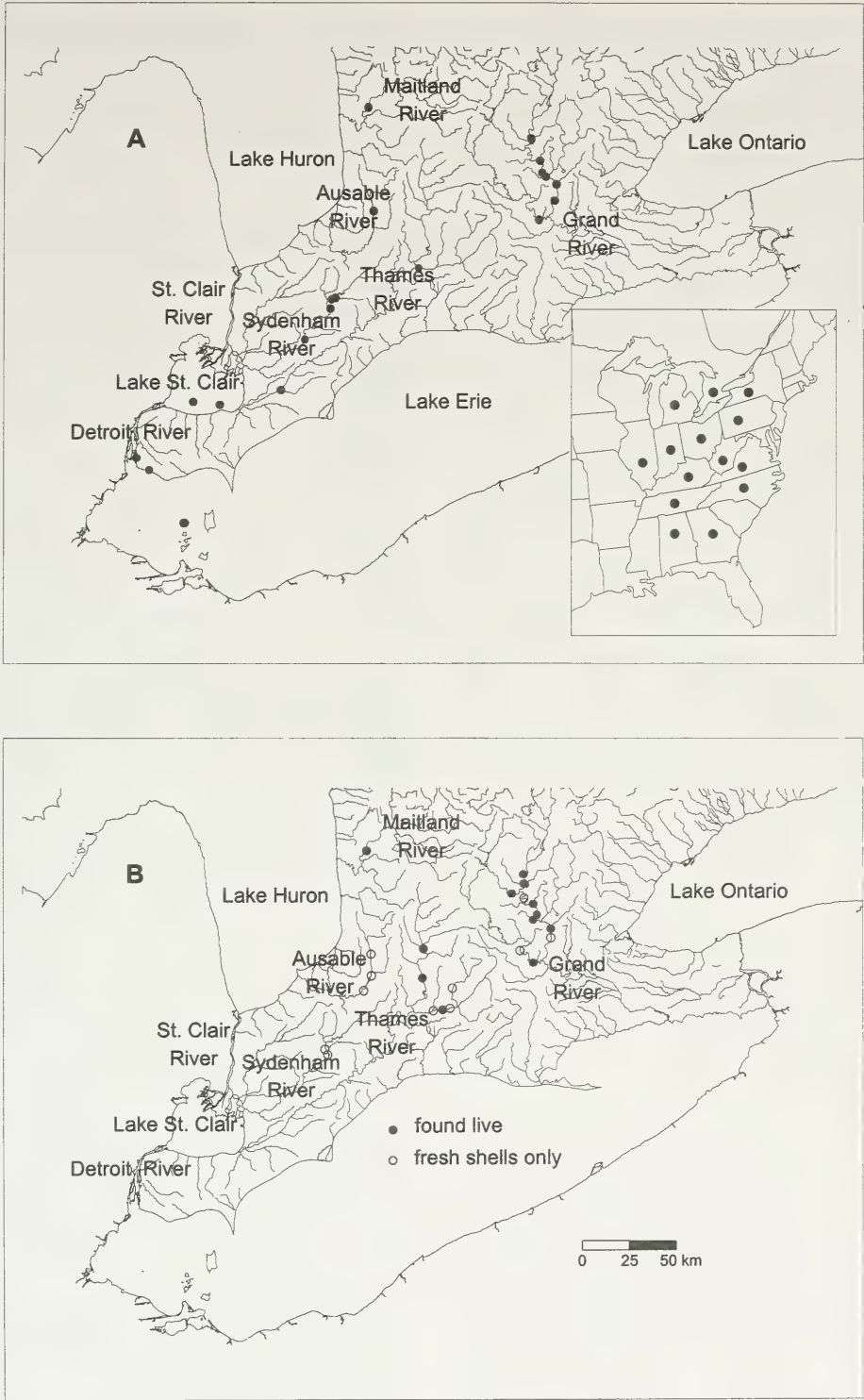


FIGURE 2. Distribution of *Lampsilis fasciola* in Ontario. A. Historical distribution (inset shows historical North American distribution). B. Presumed current distribution, based on the results of 1997-1998 surveys.

Andreae, St. Clair Region Conservation Authority, personal communication, March 1998), and the Ausable-Bayfield Conservation Authority (ABCA) owns a number of properties totalling 1830 ha throughout the Ausable basin (K. Vader, ABCA, personal communication, March 1999).

The federal Fisheries Act may represent the most important legislation protecting the habitat of the Wavy-rayed Lampmussel in Canada. Under this Act, freshwater mussels are considered to be shellfish, which are included in the definition of "fish" and therefore afforded protection in theory. In practice, the Fisheries Act is mainly applied to habitats that support recreational or commercial fisheries. As *L. fasciola* presently occurs in rivers that support recreational fisheries, its habitat should be indirectly protected by the Fisheries Act.

Lampsilis fasciola is not federally listed in the United States. However, it is listed as endangered in Illinois, threatened in Michigan, proposed for listing as threatened in New York and designated as of special concern or interest in Indiana, Ohio and North Carolina (Cummings and Mayer 1992; Strayer 1995*; TNC 1997*), and is therefore afforded protection in these states. In Michigan, for example, the destruction or possession of any species listed as endangered or threatened in the state is prohibited under the Natural Resources and Environmental Protection Act (Michigan DNR 1998*).

Population Sizes and Trends

UNITED STATES

Williams et al. (1993) described the conservation status of *L. fasciola* in North America as currently stable, which means that its "...distribution and abundance may be stable, or it may have declined in portions of its range but is not in need of immediate conservation management actions." However, Strayer et al. (1991) and Strayer and Jirka (1997) reported that the species has declined, at least in the upper Midwest, and is now rare throughout much of its former range. According to Cummings and Mayer (1992), it is widely distributed but uncommon in the northern tributaries of the Ohio River. It is also uncommon in the St. Joseph River system of the Maumee River drainage (which drains into Lake Erie), and generally uncommon in Ohio (GT. Watters, Ohio State University, personal communication, June 1998). Cummings and Mayer (1997) examined museum collections for records of freshwater mussels from Illinois, and determined that *L. fasciola* has been extirpated from the Plaines River and tributaries to Lake Michigan, the Fox River and the Wabash River, and is now occasionally found only in the Vermilion River drainage. Dennis (1984) compared recent (1970-1981) and historical (1918-1924) records for mussels from ten streams and reaches of medium-sized rivers in Tennessee and

Virginia, as well as the Allegheny River in Pennsylvania, and found that *L. fasciola* had been lost from three of these systems.

It is difficult to quantify populations trends for *L. fasciola* in the United States, as it has never been a common species. Even areas of preferred habitat have seldom yielded more than a handful of specimens during surveys. For example, only one of 281 mussels collected from 29 sites in Lake St. Clair in 1986 was *L. fasciola* (Nalepa et al. 1996). Similarly, Strayer et al. (1991) found only small numbers (1-5 specimens) of *L. fasciola* at four of 26 sites in the upper Allegheny River drainage in western New York in 1987-1990, and at an additional site in 1995 (Strayer 1995*). The species generally accounted for less than 2% of all mussels found, and the sites where it occurred were those that supported the greatest diversity of mussel species. Strayer (1979) surveyed 26 stations in small (< 20 m wide), shallow (< 1.5 m at low flow), low gradient, hardwater streams in the Lake Erie drainage of southwestern Michigan in 1976-1978. *Lampsilis fasciola* was found to be "common" (1-5 specimens collected/person-hour of sampling) at five sites, "rare" (<1 specimen/man-h) at a sixth site, and represented by dead shells only at two other sites. In 1977-1978, Strayer (1980) also surveyed 76 sites on the Clinton River, a tributary of Lake St. Clair located just north of Detroit. *Lampsilis fasciola* was found alive at two sites (2-6 specimens/site) and was represented by dead shells at six other sites, whereas it had been reported from 5 of 26 sites prior to 1935. Hoeh and Trdan (1985) surveyed 27 sites on the Black, Pine and Belle rivers (tributaries to the St. Clair River in southeastern Michigan) for mussels in 1982-1983. *Lampsilis fasciola* was found at only one site, where it was rare (<1 specimen/man-h); this particular site on Elk Creek was one of the three most diverse sites visited.

In 1973-1975, Dennis (1984) surveyed several sites along the Clinch and Powell rivers in Tennessee and Virginia that were previously found to be among the most productive sites for mussels in the Tennessee River drainage. *Lampsilis fasciola* was one of 35 species found alive in quantitative sampling (thirty-two 1m² quadrats) at Kyles Ford on the Clinch River, but only 5 of the 955 mussels collected (0.5%) were of this species. At Speers Ferry, also on the Clinch River, *L. fasciola* was not among the 23 species found during quantitative sampling; however, it was one of six additional species that were discovered during preliminary qualitative sampling. Strayer et al. (1997) have shown that qualitative sampling is more effective than quadrat sampling for detecting rare species. Four sites on the Powell River were sampled by Dennis (1984), using less effort (4-10 quadrats/site). Between one and four specimens of *L. fasciola* were found at three of these sites, accounting for 1-2% of the total mussels captured.

Dennis (1984) also sampled three sites on smaller streams, which she described as *L. fasciola*'s preferred habitat (see section on Habitat). Again, only one or two specimens of this species were found at each site on the North Fork and Middle Fork Holston rivers; however, they accounted for a greater proportion (2-4%) of the community here than in the larger rivers.

CANADA

The first record for *L. fasciola* in Canadian waters came from the Grand River near Galt, Ontario, in 1894 by Macoun (CMNML002518). It was first recorded from the Thames River in 1902 by Saunders (CMNML002542), from the Detroit River in the 1930s by Walker (UM84186), from the Maitland River in 1935 by Oughton (UM186322), from the Sydenham River in 1965 by Stein (OSUM19210), from western Lake Erie in 1967 by Condit and Forsyth (OSUM18666), from Lake St. Clair in 1986 (Nalepa et al. 1996), and from the Ausable River in 1993 (Morris and Di Maio 1998). Three of these records are for live specimens, two are for fresh shells, and the rest have no accompanying information on whether the specimens were collected live or dead. *Lampsilis fasciola* was reported again from western Lake Erie in 1980, but it was not found during a survey of 17 sites in 1991 by Schloesser and Nalepa (1994). The Detroit River has not been surveyed in recent years. Nalepa et al. (1996) surveyed 29 sites in Lake St. Clair in 1986, 1990, 1992 and 1994, and found only one live specimen of *L. fasciola* in 1986 and one in 1994. The native mussel communities of Lake Erie, Lake St. Clair and the Huron-Erie corridor have been severely impacted by Zebra Mussels, *Dreissena polymorpha* (see section on Limiting Factors). However, coastal wetlands around Lake Erie have been shown to serve as refuges where unionids can burrow deeply into the soft sediment and smother these attached pests (Nichols and Wilcox 1997). Recently, 13 live specimens of *L. fasciola* were found in shallow wetland areas with sandy substrates in the northern part of Lake St. Clair bordering the St. Clair River delta (D. Zanatta, University of Guelph, personal communication, July 1999).

Metcalfe-Smith et al. (1998b*, 1999*) surveyed 66 sites on the Grand River (Lake Erie drainage), Thames and Sydenham rivers (Lake St. Clair drainage), and Ausable and Maitland rivers (lower Lake Huron drainage) in 1997 and 1998 to assess the current conservation status of rare species of freshwater mussels in southwestern Ontario. Results of these surveys are compared with the historical data to determine population trends for the Wavy-rayed Lampmussel in these rivers.

Grand River

Only three "old" records exist for *L. fasciola* from the Grand River, and all are from the middle reaches:

single live specimens were reported from Galt (now part of the City of Cambridge) in 1894 and Glen Morris in 1929, and an occurrence (no details about numbers, or if live or dead) was recorded at Breslau in 1931 (museum records). Two major mussel surveys have been conducted on the Grand River in the past 25 years. Kidd (1973) surveyed 115 sites throughout the system in 1970-1972, and Mackie (1996*) visited 70 sites, focusing mainly on tributaries, in 1995. Kidd (1973) did not specify his sampling effort, but it is believed to have been fairly intensive as the surveys were the focus of his M.Sc. thesis research. Mackie (1996*) used the timed-search method and a sampling effort of 1.5 person-hours (p-h)/site. Kidd (1973) found two live specimens of *L. fasciola* at West Montrose, 13 shells at this and three other sites near Glen Morris and Kitchener, and two shells at a site on the Nith River (a major tributary) near Paris. The only record of this species from Mackie's (1996*) survey is for two fresh valves from West Montrose. The historical distribution of *L. fasciola* in the Grand River, based on occurrences of both live animals and shells, is shown in Figure 2A.

Metcalfe-Smith et al. (1998b*, 1999*) surveyed 24 sites on the Grand River in 1997-1998 using the timed-search method and a sampling effort of 4.5 p-h/site. All seven sites where either live specimens or shells of *L. fasciola* had previously been found were visited. A total of 27 live animals, 46 fresh whole shells and 9 fresh valves were found at eleven sites, including eight sites along a 60 km stretch of the Grand River proper between Inverhaugh and Cambridge, two sites on the Nith River, and one site on the Conestoga River (Table 1; Figure 2B). Weathered shells are not discussed because their points of origin are unknown. Population densities were greatest at the sites near Kitchener. Live animals were found at all historical sites except Glen Morris, where neither live specimens nor fresh shells were found. These data indicate that healthy populations of *L. fasciola* still persist in the middle reaches of the Grand River, but that the species may have been lost from the lower portion of its former range, i.e., between Cambridge and Glen Morris. Additional searches at several sites downstream of Cambridge in 1997 yielded only 5 living specimens of a common species, *Lasmigona costata* (Metcalfe-Smith, unpublished data). Mussels may have been lost from this reach of the river because of domestic and industrial effluents, and/or several dredging operations conducted in recent years (Peter Mason, Grand River Conservation Authority, personal communication, February 1999). The upstream limit of the species is likely to be at Inverhaugh, which is just below the Elora Gorge.

Based on his data and those from historical studies to which he had access, Kidd (1973) determined that *L. fasciola* ranked 25th of 33 species in the Grand

TABLE 1. Numbers of live specimens and spent shells of *Lampsilis fasciola* found in the Grand (GR), Thames (TR), Sydenham (SR), Ausable (AR) and Maitland (MR) rivers in 1997-1998^a. Sites ordered in an upstream to downstream direction for each river.

Site number	Nearest urban centre	Live specimens	Fresh shells		Weathered shells	
			Whole	Valves	Whole	Valves
GR-18	Inverhaugh	2 ^b	1	0	0	2
GR-13	West Montrose	1,1 ^b	0	0	2	2
GR-23 ^c	St. Jacob's	1	1	0	1	2
GR-19	Waterloo	0	5	1	1	3
GR-20	Breslau	2	6	2	0	1
GR-12	Kitchener	8,2 ^b	11	2	0	1
GR-3	Kitchener	8	13,6 ^b	4	7 ^b	0
Upstream	Cambridge	1 ^b	0	0	0	0
Downstream	Cambridge	0	1 ^b	0	0	0
GR-2	Glen Morris	0	0	0	0	1
GR-14 ^d	Plattsville	0	0	0	0	1
GR-24 ^d	Drumbo	0	1	0	0	0
GR-8 ^d	Canning	1 ^b	1	0	1	2
GR-4	Caledonia	0	0	0	0	1
GR-5	York	0	0	0	0	2
TR-13 ^e	Science Hill	1	2 ^b	0	2 ^b	2 ^b
TR-12 ^e	Plover Mills	1	1	0	0	7 ^b
TR-15 ^f	Thamesford	0	1	0	1	1
TR-11	Dorchester	0	2	0	0	1
TR-2	Dorchester	4	1	0	0	0
TR-3	London	0	1	0	0	0
SR-2	Alvinston	0	1	0	0	0
SR-3	Alvinston	0	2	0	0	0
AR-2	Exeter	0	0	0	1	0
AR-8	Brinsley	0	1	0	0	0
AR-1	Brinsley	0	0	0	0	2
AR-3	Ailsa Craig	0	2	0	0	2
AR-7	Nairn	0	2	0	0	0
MR-1	Auburn	3	2	0	1	0

^adata taken from Metcalfe-Smith et al. (1998b*, 1999*), ^bcollected during additional sampling; ^cConestoga River; ^dNith River; ^eNorth Thames River; ^fMiddle Thames River.

River in terms of abundance. Of 1495 live mussels collected from the river between 1885 and 1972, only 4 (0.3%) were *L. fasciola*. In contrast, just under 2% of the 1568 mussels collected from the system in 1997-1998 were *L. fasciola*. The reason for this difference in relative dominance may be that the surveys of 1997-1998 focused on sites known to have supported rare species in the past. Current densities of *L. fasciola* in the Grand River, and its relative dominance within the mussel community, appear to be typical of populations elsewhere in North America.

Shell lengths of most live *L. fasciola* collected from the Grand River during formal surveys and extra searches in 1997-1999 ranged from 51 to 66 mm, but two females were considerably smaller (30 and 44 mm) and two males were much larger (90 and 91 mm). Weathered and fresh shells (n = 85) measured between 27 and 93 mm in length, with female

shells being smaller, on average, than male shells (mean lengths 61 and 67 mm, respectively). The maximum size observed (93 mm) is similar to the maximum size reported for this species in Canada (95 mm, Clarke 1981). Four of the 19 live specimens that were sexed were males and 15 were females, suggesting a scarcity of males in the system. As the sex ratio for shells was more even (47 males to 38 females), the skewed ratio for live animals may be a function of the small sample size. The presence of several small specimens is indicative of recent recruitment, but the restricted size range of most live specimens implies the failure of some year classes.

Thames River

There are only three historical (museum) records for *L. fasciola* from the Thames River; one fresh whole shell was recorded from Chatham in 1902, and "occurrences" (not known if live or dead) were

reported from an unknown location in 1931 and at London in 1936 (Figure 2A). Although the Lower Great Lakes Unionid Database (described earlier) contains 400 records of unionids collected from a total of 112 sites on the Thames River between 1894 and 1995, there are no records for *L. fasciola* after 1936. In his synopsis of the mollusca of Middlesex County, Ontario, Diamond (1940) did not list *L. fasciola* among the species occurring in the Thames River. Morris (1996*) and Morris and Di Maio (1998) surveyed 46 sites throughout the Thames River system in 1994-95 using a sampling effort of 1 p-h/site, and found no trace of this species.

Metcalf-Smith et al. (1998b*, 1999*) surveyed 16 sites on the Thames River in 1997-98 and found evidence of *L. fasciola* at six sites in the upper reaches of the system, i.e., the upper Thames, North Thames and Middle Thames (Table 1; Figure 2B). A total of six live animals were found at three of these sites. All were large (shell lengths 58-83 mm), which may indicate that the species is no longer reproducing in the system. *Lampsilis fasciola* accounted for only 0.3% of the 1890 live mussels collected from the river in 1997-1998.

Sydenham River

Lampsilis fasciola was first recorded from the Sydenham River about 30 years ago. Four fresh whole shells were collected near Florence in 1965 by C. B. Stein, who also collected two live animals and eight fresh whole shells near Alvinston in 1967 (museum records). The species was also found near Shetland in 1967 by H. D. Athearn (personal collection), but he did not indicate if the specimens were dead or alive. The first extensive survey of the Sydenham River was conducted in 1971 by Clarke (1973). He visited 11 sites using a sampling effort of 1 p-h/site, and observed one live specimen of *L. fasciola* at a site above Alvinston. Mackie and Topping (1988) surveyed 20 sites in the system in 1985 using the same sampling effort as Clarke, and reported dead shells only at an undisclosed number of sites on the north Sydenham River. In a further investigation of 16 sites in 1991, Clarke (1992) found no trace of this species.

Metcalf-Smith et al. (1998b*, 1999*) surveyed 17 sites on the Sydenham River in 1997-1998, including the four sites where *L. fasciola* had been observed between 1963 and 1971. No live specimens were found at any site, but three fresh whole shells measuring 56, 67 and 76 mm (all females) were found at two sites below Alvinston (Table 1). Although the data are very limited, they suggest that the species has either been lost from the Sydenham River or its range has been contracted.

Ausable and Maitland Rivers

To our knowledge, there are no historical records for *L. fasciola* from the Ausable River. Morris and

DiMaio (1998) surveyed six sites on the river in 1993-1994 using a sampling effort of 1 p-h/site, and found a single live specimen near Brinsley. Eight sites were surveyed in 1997-1998 (Metcalf-Smith et al. 1998b*, 1999*), including the Brinsley site, but no live specimens were encountered. A few fresh whole shells and several weathered shells or valves were found in the upper portion of the river between Exeter and Nairn (Table 1; Figure 2B). All shells had come from large (60-85 mm), presumably old, specimens.

L. fasciola was recorded from a site on the Maitland River at Auburn in 1935 (museum record). In 1998, one live female (60 mm shell length), two live males (66 and 69 mm), and three whole shells (46, 54 and 68 mm), were found at the same site (Table 1; Figure 2B). The species constituted nearly 10% of all live unionids found. As this was the only site surveyed in recent years, the results are encouraging. Clearly, additional surveys should be conducted in this river to determine if it harbours a significant population of the Wavy-rayed Lampmussel.

Habitat

According to Clarke (1981) and Cummings and Mayer (1992), the Wavy-rayed Lampmussel lives mainly in gravel or sand bottoms of riffle areas in medium-sized streams. Strayer and Jirka (1997) reported that *L. fasciola* typically lives in and around riffles in clear, hydrologically stable (i.e., having steady flows and stable substrates) rivers and large creeks. In southeastern Michigan, Strayer (1983) reported this species as occurring in medium-sized and large streams on the outwash plains. Such streams are characterized by low gradients, clear water, steady flows, and substrates of sand and gravel. Dennis (1984) examined recent and historical mussel records for the Tennessee River basin, including her own data from comprehensive surveys conducted between 1973 and 1981, and determined the stream size and habitat associated with 72 different species. *Lampsilis fasciola* was typical of small to medium-sized streams, where small streams were defined as 2nd to 4th order meandering "creeks" and medium-sized streams were defined as 5th to 7th order small rivers. In both environments, the most productive areas for mussels of all species were shoals with stable substrates consisting of mixtures of fine particles, gravel and rocks. *Lampsilis fasciola*, and two species with which it frequently co-occurred (*Elliptio dilatata* and *Lasmigona costata*), were found to "...commonly inhabit muddy gravel substrates in areas of moderate to slow current, and will tolerate some silt deposition during periods of low flow." (Dennis 1984). Habitats in Ontario where *L. fasciola* were found alive in 1997-1998 were generally characterized as clean sand/gravel substrates, often stabilized with cobble

or boulders, in steady currents at depths of up to 1 metre.

General Biology

Although the specific biology of *Lampsilis fasciola* is not well known, general unionid biology is applicable (USFWS 1994*). The Wavy-rayed Lampmussel is a medium-sized, sexually dimorphic mussel that has been shown to live at least 10 years (Kidd 1973; Dennis 1984), but rarely more than 20 years (G. T. Watters, Ohio State University, personal communication, June 1998). During spawning, males release sperm into the water and females living downstream take in the sperm via their incurrent siphons. Female mussels brood their young from the egg to the larval stage in their gills, using the posterior portions of their outer gills as marsupia. The shell of the female is distended along the posterior ventral margin to accommodate the expanded gill pouches, a feature that is called a marsupial swelling. *Lampsilis fasciola* is a long-term brooder (bradytic). Spawning occurs in August, and glochidia (larvae) are released the following May through August in Virginia (Zale and Neves 1982) and July through August in Canada (Clarke 1981). Glochidia may also be released in the autumn of the same year that they spawn (Watters and O'Dee 1996).

In females of the genus *Lampsilis*, the edge of the mantle has evolved into a minnow-shaped lure (Strayer and Jirka 1997). When the glochidia are ready for release, the female waves her lure to attract potential fish hosts. Figure 3 shows the typical lure of a female *L. fasciola*, which was observed at a site

on the Grand River in 1997. Females displaying unusual reddish-orange mantle flaps were also observed. It is believed that the two variations in mantle flap morphology, which may occur in the same population, represent either pronounced polymorphism or sibling species (A. E. Bogan, Curator of Aquatic Invertebrates, North Carolina State Museum of Natural Sciences, personal communication, June 1998; G. T. Watters, Ohio State University, personal communication, June 1998). If the latter is true, then the conservation status of this/these species will have to be re-evaluated. When the mantle flaps of a gravid female are touched by a fish, they are withdrawn and the shell closes on the marsupia, resulting in the release of glochidia (Watters and O'Dee 1996). Once expelled into the water by the female, the glochidia must attach to an appropriate fish host in order to complete their metamorphosis. The glochidia of *L. fasciola* are purse-shaped and without spines (Clarke 1981). They are 290 high and 250 long (Hoggarth 1993). Glochidia that are higher than long are mostly gill parasites. This morphological feature tends to maximize the chance of a successful encounter, while sacrificing adductor muscle strength that may be less important for maintaining attachment to the protected surface provided by gills.

The only known fish hosts for *L. fasciola* are the Smallmouth Bass, *Micropterus dolomieu* (Zale and Neves 1982), and Largemouth Bass, *Micropterus salmoides* (G. T. Watters, Ohio State University, unpublished data), both of which are common in the waters of southern Ontario. There may be other suitable hosts; however, metamorphosis was not record-

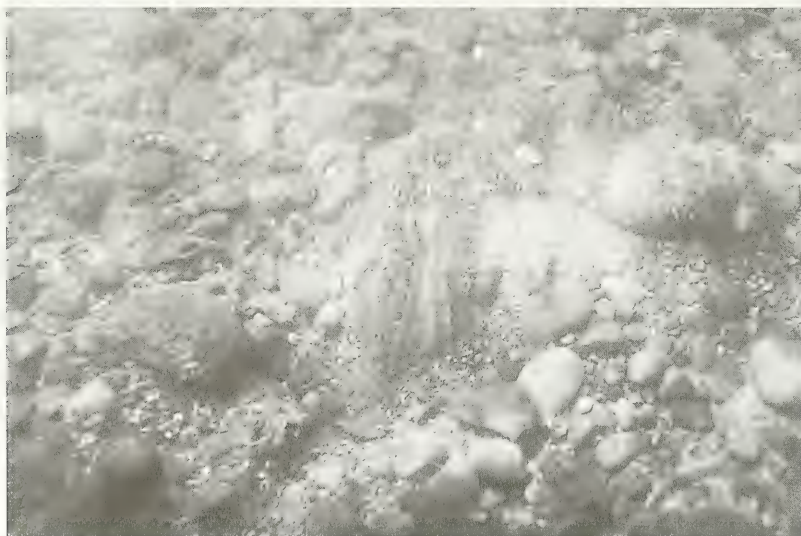


FIGURE 3. A gravid female *Lampsilis fasciola* found in the Grand River, Ontario, displaying the typical minnow-shaped lure complete with eye spots and pigmented marking.

ed from any of 16 species of minnows, sunfishes, suckers and perches in laboratory tests (Watters and O'Dee 1996). Data obtained from the Royal Ontario Museum and the Ontario Ministry of Natural Resources' Ontario Fisheries Information System on the distributions of Smallmouth Bass and Largemouth Bass indicate that both species are found in the Grand, Thames, Sydenham and Ausable Rivers. In all systems except the Sydenham River, the Smallmouth Bass was represented by more records than the Largemouth Bass. This is not surprising, as the flowing water and rocky substrates of most rivers are most suited to Smallmouth Bass, whereas Largemouth Bass are almost universally found in association with soft bottoms, stumps, and extensive growths of aquatic vegetation (Scott and Crossman 1973). As *L. fasciola* generally inhabits gravel or sand bottoms of the riffle areas of medium-sized streams, the Smallmouth Bass is most likely the functional host for this mussel in Ontario waters. Although no data were acquired on the fish community of the Maitland River where *L. fasciola* was also found, Smallmouth Bass were seen during field work at the only site surveyed in this watershed in 1997-1998.

In *L. fasciola*, both respiration and feeding occur by means of the gills. As water is pumped through the gills by the inhalant siphon, food and oxygen are removed. Because water flow may aid the filtering process, many mussels prefer flowing water. Although *L. fasciola*'s exact food preferences and optimum particle sizes are not known, they are probably similar to those of other freshwater mussels, i.e., suspended organic particles such as detritus, bacteria and algae (TNC 1986*).

Limiting Factors

Impoundments, siltation, pollution, Muskrat (*Ondatra zibethicus*) predation and Zebra Mussels (*Dreissena polymorpha*) and are known to threaten the Wavy-rayed Lampmussel in portions of its North American range. Reservoirs alter downstream water temperature and velocity, and isolate upstream populations of mussels from their fish hosts (Biggins et al. 1995*). *Lampsilis fasciola* was one of 26 species extirpated from "Mussel Shoals", a 53-mile reach of the Tennessee River that was once the richest area in the world for mussels, after the construction of the Wilson Dam in 1925 (Dennis 1984). Erosion resulting from deforestation, poor agricultural practices and the destruction of riparian buffer zones cause siltation, which can suffocate mussels, interfere with their feeding, and create unstable substrates (Dennis 1984; Keller and Zam 1990). Susceptibility to siltation differs from species to species; *L. fasciola* can apparently tolerate some silt deposition during low flow periods (Dennis 1984). Siltation also has an indirect effect on mussels by transporting pollutants.

The specific effects of most environmental con-

taminants on unionids are not known, but there is evidence that compounds such as PCBs, DDT, Malathion and Rotenone inhibit respiration and accumulate in the tissues of mussels (USFWS 1994*). During the glochidial stage, mussels are particularly sensitive to heavy metals (Keller and Zam 1990), ammonia from wastewater treatment plants (Goudreau et al. 1993), acidity (Huebner and Pynnonen 1992) and salinity (Liquori and Insler, as cited in USFWS 1994*). Jacobson et al. (1997) determined the toxicity of dissolved copper to the released glochidia of five species of unionids. They found that *L. fasciola* was the most sensitive to copper ($LC_{50} = 26-48 \mu\text{g/L}$), while the common floater, *Pyganodon grandis*, was the least sensitive ($LC_{50} = 46-347 \mu\text{g/L}$).

Predation by Muskrats is a potential limiting factor for some mussel species. For example, Muskrat predation is inhibiting the recovery of endangered mussel species in the Tennessee River drainage, and likely contributing to further population declines (Neves and Odom 1989). Muskrats could potentially be a severe threat to small populations of *L. fasciola*, as they tend to prey on mussels with shell lengths of about 45-65 mm (Convey et al. 1989; Neves and Odom 1989) or up to 70-120 mm (Watters 1993-1994). In fact, Neves and Odom (1989) found that Muskrats actually preferred *L. fasciola* over other species. During an eight-year period, Muskrats consumed 47% of the adults of this species from a site on the North Fork Holston River, Virginia, in contrast to only 9-24% of adults of other species.

Zebra Mussels have decimated native mussel communities in Lake St. Clair (Nalepa et al. 1996) and western Lake Erie (Schloesser and Nalepa 1994), which were historically a part of *L. fasciola*'s range. As the Wavy-rayed Lampmussel is primarily a riverine species, with only about 15% of records from Ontario waters prior to 1990 occurring in areas now infested with Zebra Mussels (Metcalf-Smith et al. 1998b*), it seems that these pests should not pose a serious threat to the continued existence of *L. fasciola* in Canada. However, "...Recent discoveries of Zebra Mussel populations in small North American rivers suggest that given an upstream source of veligers competent to settle, some small rivers can provide suitable habitat for Zebra Mussels" (Hunter et al. 1997). The presence of dams and reservoirs may greatly increase the likelihood of Zebra Mussels successfully colonizing a river system.

In the Grand River, sedimentation and pollution from urban and agricultural runoff are major threats to water and habitat quality for *L. fasciola* and other mussel species. As the human population continues to grow, siltation from major construction projects and the input of pollutants and pathogens from sewage treatment plants and stormwater runoff will increase. According to the Grand River Conservation Authority (GRCA 1997*), the number of people dis-

charging wastewater into the river is expected to increase from 600 000 to 900 000 over the next 25 years. Agricultural activities are also increasing in the basin (WQB 1989a*); thus, runoff of sediment, pesticides, fertilizers and livestock manures from surface and tile drainage will also increase. Clearing of riparian vegetation and allowing livestock access to waterways also contribute to the destruction of mussel habitat. Water quality has been described as "satisfactory" in the Grand River basin, but "poor" in the Nith River (WQB 1989a*). *Lampsilis fasciola* still occurs in the upper reaches of the Grand River, which is the only portion of the basin where copper concentrations do not exceed the federal aquatic life guideline.

The Grand River is significantly impounded, with 34 dams and weirs along its course (GRCA 1998*). Dams cause changes in the substrate, particularly an accumulation of silt, and act as barriers to fish movement. Watters (1995) demonstrated that dams as low as 1 metre may prevent the upstream movement of some fishes, hence limiting the dispersal of mussels that use these fishes as hosts. Fishways were not installed in the Grand River until the 1990s (GRCA 1998*).

Because of its dams, the Grand River is significantly at risk for Zebra Mussel colonization. Reservoirs with retention times greater than 20-30 days allow veligers enough time to develop and settle, and the impounded populations will then "seed" downstream reaches on an annual basis. Should Zebra Mussels become established in the Luther, Belwood, Guelph, or Conestogo reservoirs, they could seriously impact the reach of the river where *L. fasciola* presently occurs.

As noted (see General Biology), the most likely fish host for *L. fasciola* in Ontario waters is the Smallmouth Bass. Although the upper Grand River supports the healthiest remaining populations of *L. fasciola* in the province, its fish host may be declining here. Cooke et al. (1998) used Catch Per Unit Effort (CPUE) data from the Grand River Bass Derby to show that the relative abundance of Smallmouth Bass has decreased significantly in the past 10 years in the reach of the river bounded by West Montrose and the Parkhill Dam in Cambridge. These findings raise concerns that increased angling pressure in the Grand River could reduce Smallmouth Bass populations to levels that will no longer sustain *L. fasciola*.

Another potential threat to unionid communities is the recreational use of waterways, particularly by canoeists. When a canoeist takes a stroke in shallow waters, the paddle often disturbs the riverbed. This can dislodge mussels from the substrate and cause them to be washed downstream, perhaps into unsuitable depositional areas. During mussel surveys in 1997-1998, the authors observed heavy canoe traffic on the Grand River, especially in the upper reaches.

At some sites, the substrate was extensively disturbed. As canoeing is becoming an increasingly popular form of outdoor recreation in Ontario, the impact of this activity on mussel populations that are already declining or under stress could become significant.

According to a recent report on the geology, land use and water quality of the Thames River (WQB 1989b*), run-off from agricultural land and seepage from rural septic systems have a major impact on water quality in this system. Tile drainage systems, wastewater drains, manure storage and spreading, and insufficient soil conservation practices all contribute to the impairment of water and habitat quality in the Thames River. Soil and streambank erosion in the Thames River basin is severe, causing high suspended sediment loads. There has been a steady increase in phosphorus and nitrogen inputs to the Thames River, and some of the highest livestock phosphorus loadings for the entire Great Lakes basin are attributable to the Upper Thames basin (WQB 1989b*). All industrial outfalls and 70% of municipal outfalls are located in the heavily-populated upper reaches, where *L. fasciola* is extant. Despite recent efforts to improve water quality throughout the basin, poor water quality still exists in some areas. Specifically, mean ammonia concentrations in all sub-basins exceed the federal freshwater aquatic life guidelines, and mean concentrations of copper exceed the guideline in several sub-basins, including those where small numbers of *L. fasciola* were found in 1997-1998. Dissolved copper levels may constitute a significant threat to the continued survival of *L. fasciola* in the Thames River; as noted earlier, this species may be particularly sensitive to copper. Thirty percent of the mussel species historically known from the Thames River were not found alive in 1997-1998 (Metcalf-Smith et al. 1999*). Species losses from the Grand and Sydenham rivers were considerably lower (24% and 15%, respectively), suggesting that the Thames River is most in need of action to restore its native mussel fauna.

Agriculture is the primary land use in the Sydenham and Ausable river basins. Cash crops, pasture and woodlots predominate in the Sydenham River watershed (Muriel Andreae, St. Clair Region Conservation Authority, personal communication, March 1998), whereas row crops (corn, beans) and livestock farming are most common in the Ausable River watershed (ABCA 1995*). There are no reports available on land use or water quality in the East Sydenham River where *L. fasciola* has most often been found. However, a report on the North Sydenham River (Bear Creek) notes an "...abundance of high intensity farming, extensive artificial drainage systems and a lack of significant idle or forested areas" (WQB 1990*). Clarke (1992) found many riffle-dwelling species to be missing from his collections throughout the system in 1991, and

TABLE 2. Water clarity at the 66 sites surveyed for mussels on the Maitland, Grand, Thames, Ausable and Sydenham rivers in 1997-1998.

River	# sites surveyed	Water clarity (cm)*		# sites over 45 cm
		Range	Mean	
Maitland	1	100	100	1
Grand	24	10-150	55	13
Thames	16	7-100	50	10
Ausable	8	6-65	35	2
Sydenham	17	7-60	20	1

*water clarity is defined as the maximum depth at which the streambed is clearly visible.

blamed this on a lack of clean, silt-free riffle habitat. Water quality in the Ausable River is generally poor because of runoff from agricultural lands, septic system seepage, and pollution from manure (ABCA 1995*). About 60% of the soils are artificially drained, which decreases base flows and contributes to flooding during storm events. Sediment loadings are high. The natural course of the lower portion of the river was destroyed in the late 1800s, when it was diverted in two places to alleviate flooding.

It is puzzling that the Wavy-rayed Lampmussel is doing poorly in the Sydenham and Ausable rivers, while another endangered riffle-dwelling species, the Northern Riffleshell (*Epioblasma torulosa rangiana*), is still found in both systems. We speculate that *L. fasciola* may have a critical requirement for clear water during reproduction, as the female must rely on good visibility in order to attract a sight predator such as the Smallmouth Bass with her lure. The Northern Riffleshell, on the other hand, displays a pure white mantle lining that can be seen for several metres even in turbid water. A displaying female *E. t. rangiana* was seen by one of us (S. K. Staton) at a site on the Sydenham River with a water clarity reading (i.e., maximum depth at which the streambed was clearly visible) of only 20 cm. Field data from the 1997-1998 surveys support the above hypothesis. At all sites on the Grand, Thames and Maitland rivers where *L. fasciola* was found alive in 1997-1998, water clarity ranged from 45 cm to 150 cm (mean = 80 cm). As shown in Table 2, over half of the sites on the Grand and Thames rivers, as well as the single site surveyed on the Maitland River, had water clarity values of greater than 45 cm. In contrast, only 3 of 25 sites on the Sydenham and Ausable rivers had water this clear.

Special Significance of the Species

Lampsilis fasciola is one of five species of the genus *Lampsilis* that occur in Canada. Although three of these species are common and widespread, *L. fasciola* and *L. cariosa* (the Yellow Lampmussel) are uncommon and have very restricted ranges. The Wavy-rayed Lampmussel may be an excellent indicator of high quality mussel habitat, as it is usually

found at sites supporting diverse mussel communities and there is some evidence that it may be very sensitive to toxic chemicals (see Limiting Factors).

Evaluation

The Wavy-rayed Lampmussel's historical range in North America spanned thirteen states and the Province of Ontario. The species has always been uncommon; however, there is general agreement that it has significantly declined in distribution and abundance in recent years, particularly in the upper Midwest. *Lampsilis fasciola* is ranked as globally common (G4) by The Nature Conservancy (TNC 1997*), and its current sub-national ranks are S1 in Ontario and North Carolina, S2 in Illinois, Indiana and Michigan, S4 in Pennsylvania and Virginia, and S4S5 in Kentucky. It was recently uplisted from S4 to S1 in New York (K. Schneider, New York State Department of Environmental Conservation, personal communication, March 1998). Sub-national ranks are not available for the southern states within its range. In Ontario, *L. fasciola* has been found alive at only a dozen or so sites in the Grand, Thames, Ausable and Maitland rivers and Lake St. Clair over the past decade.

Lampsilis fasciola inhabits clear, hydrologically stable rivers and streams of a variety of sizes, where it is typically found in gravel or sand substrates in and around riffle areas. It faces a variety of threats throughout its range, and is especially vulnerable to impoundment, siltation and pollution. For example, dams have caused the extirpation of *L. fasciola* from several rivers in the United States. Water and habitat quality have declined throughout a significant portion of the species' historical range in southwestern Ontario as a result of urban expansion and intensifying agriculture. Zebra Mussels have severely impacted *L. fasciola* in Lake Erie, Lake St. Clair and the Detroit River, and could jeopardize its existence in impounded rivers if they ever colonize the reservoirs. There is some evidence that *L. fasciola*'s most probable fish host, the Smallmouth Bass, is declining in the upper Grand River due to fishing pressure.

Lampsilis fasciola constituted 2% of all live mussels found in the Grand River during intensive sur-

veys in 1997-98. In contrast, only 0.3% of specimens found in the generally more productive Thames River were of this species. The absence of *L. fasciola* from the Sydenham and Ausable rivers may be attributed to poor water clarity. As *L. fasciola* constituted 10% of the mussel community at the one site surveyed on the Maitland River, further surveys should be conducted to determine if the river is a significant refuge for this species. It appears that the healthiest remaining populations of *L. fasciola* in Canada occur in a 60 km stretch of the upper Grand River. There is good potential for stabilizing or enhancing this population, provided that water quality conditions do not deteriorate and disturbances associated with recreational activities can be minimized. There is less likelihood of strengthening the Thames River population due to the severely degraded condition of the upper reaches.

The status of Endangered is recommended for the Wavy-rayed Lampmussel in Ontario and Canada for four main reasons: (1) The species has been lost from most of its former range in Canada as a result of anthropogenic impacts and Zebra Mussels, and the populations that remain are at continued risk from these threats. (2) Existing populations are fragmented and occupy only short reaches of several river systems and a few sites in the northern portion of Lake St. Clair. Assuming that fresh shells indicate the presence of live animals and that populations are continuous between adjacent sampling sites, the species is very optimistically presumed to occupy a 60 km reach of the Grand River, 8 km of the Thames River, 24 km of the North Thames River, 5 km of the Sydenham River and 21 km of the Ausable River. As average stream widths for these reaches are 75 m, 35 m, 25 m, 20 m, and 10 m, respectively (Metcalf-Smith, unpublished data), the total area presently occupied by this species in Canada is only about 5.5 km² (excluding refuge sites in Lake St. Clair that have not been quantified). (3) The species' most probable fish host in Canada, the Smallmouth Bass, has declined significantly over the past 10 years in the stretch of the upper Grand River that currently supports the healthiest remaining populations in the country. (4) *L. fasciola* appears to have a critical requirement for clear water because of its reproductive strategy. If so, water clarity may become the most significant factor limiting the distribution of this species in southwestern Ontario rivers in the future. This manuscript is based on the reports to COSEWIC and COSSARO, but has been updated to incorporate new data collected in 1998.

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Immobilization of Free-ranging Rocky Mountain Bighorn Sheep, *Ovis canadensis canadensis*, Ewes with Telazol® and Xylazine Hydrochloride

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We determined the efficacy of immobilizing human-habituated, free-ranging Rocky Mountain Bighorn ewes (*Ovis canadensis canadensis*) with Telazol® and xylazine hydrochloride (HCl) in summer and winter. Eleven sheep were approached from the ground and darted with one of three drug doses between 1995 and 1998. Mean induction time for the winter recommended dose (250:30 Telazol® and xylazine HCl) was 20.4 min (SD = 6.0, range = 14 to 27) and duration of immobilization averaged 78.3 min (SD = 20.2, range = 59 to 99). Mean induction time for the summer recommended dose (370:30 Telazol® and xylazine HCl) was 19 min (SD = 3.6, range = 15 to 22) and the mean duration of immobilization was 56 min (SD = 19.8, range = 42 to 70). Immobilization response times were not different by season, pregnancy status, or lactating state of ewes. When combined with Telazol®, the xylazine HCl dose required for effective immobilization was less than reported in other studies where xylazine HCl was used in combination with other drugs or used alone to immobilize Bighorn Sheep. In this study, 250 mg of Telazol® (4.2 mg/kg) and 30 mg xylazine HCl (0.5 mg/kg) in winter and 370 mg of Telazol® (6.2 mg/kg) and 30 mg of xylazine HCl (0.5 mg/kg) in summer provided effective and safe immobilization of human-habituated, free-ranging Bighorn ewes with minimal side effects.

Key Words: Bighorn Sheep, *Ovis canadensis canadensis*, dart, ewe, ketamine, immobilization, Telazol®, tiletamine, xylazine, yohimbine, zolazepam, South Dakota.

Bighorn Sheep (*Ovis canadensis*) have been chemically immobilized with xylazine hydrochloride (HCl) (Jessup et al. 1985; Jorgenson et al. 1990), as well as combinations of xylazine HCl with etorphine HCl (Jessup et al. 1982; Kock et al. 1987), haldin-isonone phosphate and atrophine sulfate (Bates et al. 1985), ketamine HCl (Festa-Bianchet and Jorgenson 1985), and carfentanil (Kock et al. 1987a). These combinations are used to minimize drug doses and recovery times that characterize immobilization when xylazine HCl is used alone (Festa-Bianchet and Jorgenson 1985; Jessup et al. 1985; Jorgenson et al. 1990). Opioids such as etorphine HCl and carfentanil may be undesirable because they are potentially lethal to humans at low doses, expensive, difficult to obtain, and may not adequately relax muscles in ungulates (Kreeger 1997).

Telazol® is a dissociogenic comprised of a 1:1 combination of tiletamine HCl and zolazepam HCl. Tiletamine HCl is a dissociative anesthetic similar to ketamine HCl but more potent; zolazepam HCl is a benzodiazepine tranquilizer similar to diazepam (Thurmon et al. 1972). Telazol® can effectively immobilize many species (Schobert 1987; Kreeger

1997), but it is usually administered in combination with a tranquilizer or sedative to improve inductions, recoveries, and muscle relaxing qualities (Kreeger 1997). The combination of Telazol® and xylazine HCl has been used successfully to immobilize Rocky Mountain Elk (*Cervus elaphus nelsoni*) (Millspaugh et al. 1995) and was more effective in immobilizing White-tailed Deer (*Odocoileus virginianus*) than either xylazine HCl alone (Schultz et al. 1992) or the combination of ketamine HCl and xylazine HCl (Ballard et al. 1998).

Our objective was to determine the efficacy of Telazol® and xylazine HCl in combination to immobilize human habituated, free-ranging Rocky Mountain Bighorn ewes (*O. c. canadensis*) from the ground in summer and winter. To our knowledge, use of this drug combination to immobilize Bighorn Sheep has not previously been published.

Methods

Bighorn Sheep were darted in Custer State Park, South Dakota (USA) (43° 45'N, 103° 22'W) between January 1995 and April 1998. The sheep were habituated to human activity and readily darted from

the ground. Cap-chur® projector darts (Palmer Chemical and Equipment Co., Douglasville, Georgia, USA) and Pneu-darts® (Pneu-Dart, Inc., Williamsport, Pennsylvania, USA) were used to deliver the drug in the gluteus maximus, gluteus medius, or vastus lateralis with a Cap-chur® or Pneu-dart® gun.

Our review of the drug combination took place in two stages. In the first stage, three adult ewes were immobilized in the winter of 1995 to establish appropriate drug doses and remove non-functioning radio-collars. These sheep were successfully immobilized with a 2.5 ml dose containing 250 mg of Telazol® (Fort Dodge Laboratories, Inc., Fort Dodge, Iowa, USA) and 30 mg of xylazine HCl (Rompun®, Haverlockart Inc., Shawnee, Kansas, USA). This concentration was created by reconstituting 500 mg of Telazol® with 3 ml of xylazine HCl (20mg/ml) and 2 ml of sterile water.

After successful immobilization, a blindfold was placed over the animal's eyes and respiration rate (breaths/min) was recorded every 5 minutes. Four ml of Durapen (Vedco, Inc., Overland Park, Kansas, USA), a penicillin antibiotic, and 2.5 ml of vitamin E and selenium (E-SE®, Scherling-Plough Animal Health Corp., Kenilworth, New Jersey, USA) were administered intramuscularly. If the animal's eyes remained open, an ophthalmic ointment (Vetropolycin, Pitman-Morre, Inc., Mundelein, Illinois, USA) was applied to prevent corneal drying. Three time responses were recorded: (1) Time when the animal was recumbent and no longer moving (Still); (2) Time when the animal was approached (Induction); (3) Time when the animal first got up and walked (Walking). Sheep were not stimulated to walk after the radio-collars were removed, but were observed from a distance. All time responses were measured as elapsed time from drug injection.

In the second phase of the study, we immobilized sheep in 1997 and 1998 to continue our evaluation of the drug combination and attach new radio-collars (Lotek Engineering, Inc., Newmarket, Ontario, Canada). In summer 1997, three adult ewes received

the same drug combination that was administered in winter 1995 (250 mg of Telazol® and 30 mg of xylazine HCl). However, in summer this concentration produced insufficient sedation for safe handling. We increased the dose to 3.7 ml (370 mg of Telazol® and 44 mg of xylazine HCl). This dose induced an adequate state of sedation in an adult ewe and a yearling ram in summer, but immobilization was prolonged (> 2 hours). In an attempt to speed recovery, we reduced the xylazine HCl component by rehydrating 500 mg of Telazol® with 2 ml of xylazine HCl (20 mg/ml) and 3 ml of sterile water. We successfully immobilized two adult ewes in the summer and one adult ewe in the winter using 3.7 ml of this combination (370 mg of Telazol® and 30 mg of xylazine HCl).

In the second phase, handling procedures described for the first phase were repeated. Additional biological and time response data were also collected. Pulse rate (beats/min) and rectal temperature (°C) was recorded every 5 minutes when feasible (Table 1). Blood, fecal samples, and standard body measurements were taken and lactating state was recorded. Weights were obtained on four sheep. Three additional time responses were also recorded for a total of six: (1) Time when the animal first laid on the ground (First Down); (2) Still; (3) Induction; (4) Time when the animal first lifted its head (Head Up); (5) Walking; (6) Time when the animal was able to maneuver without stumbling or falling (No Fall). Immobilization duration was defined as the time from induction to the time when the animal first walked. All time responses were measured as elapsed time from drug injection.

One-way analysis of variance was used to compare time responses by factors of season and reproductive and lactating states (Zar 1996). All analyses were considered significant at the $P < 0.10$ level. One ewe that received an unknown amount of drug, one ewe that received the lightest dose in summer and departed before complete handling, and a yearling ram which died due to a dart related injury were not included in our analyses.

TABLE 1. Mean \pm SD (N) vital signs of Rocky Mountain Bighorn Sheep monitored during immobilization by Telazol® and xylazine HCl in Custer State Park, South Dakota between 1995–1998.

Time (minutes)	Summer			Winter		
	Respiration (breaths/minute)	Pulse Rate (beats/minute)	Temperature (°C)	Respiration (breaths/minute)	Pulse Rate (beats/minute)	Temperature (°C)
0	64 \pm 26.7 (4)	75 \pm 7.1 (2)		55 \pm 22.2 (4)	—	—
5	53.3 \pm 25.7 (3)	48 (1)	39.9 \pm 1.2 (3)	58 \pm 17.7 (4)	—	38.9 (1)
10	60 \pm 23.2 (5)	69.3 \pm 4.6 (3)	38.8 \pm 0.8 (3)	53 \pm 17.4 (4)	—	38.4 (1)
15	59.2 \pm 18 (5)	64 \pm 12 (3)	38.7 \pm 0.9 (3)	58 \pm 14.8 (4)	—	37.7 (1)
20	68 \pm 5.7 (4)	64 \pm 6.9 (3)	39.1 \pm 0.3 (2)	45 \pm 14.4 (2)	—	37.7 (1)
25	63 \pm 12.8 (4)	70 \pm 8.5 (2)	39 \pm 0.3 (2)	36 (1)	60 (1)	38.2 (1)
30	61 \pm 19.7 (4)	74 \pm 8.5 (2)	39.3 \pm 2 (3)	58.7 \pm 4.6 (3)	68 (1)	38.1 (1)

Results

Mean (SD) respiration rate was 56.6 (8.1) breaths per minute, mean (SD) pulse rate was 65.8 (8.2) beats per minute, and mean (SD) temperature was 38.7 (0.7) °C for both seasons combined.

In the summer it appeared that a higher dose of Telazol® was required to produce an adequate state of sedation for safe handling. Based on a 60 kg ewe, effective immobilization required 250 mg of Telazol® (4.2 mg/kg) and 30 mg xylazine HCl (0.5 mg/kg) in winter and 370 mg of Telazol® (6.2 mg/kg) and 30 mg of xylazine HCl (0.5 mg/kg) in summer. There were no seasonal differences detected in time responses (Table 2).

Time to induction in our study for the 250:30 Telazol® and xylazine HCl dose was 20.4 min (SD = 6.0, range = 14 to 27) and duration of immobilization was 78.3 min. (SD = 20.2, range 59 to 99). For the 370:30 Telazol® and xylazine HCl dose, time to induction was 19 min. (SD = 3.6, range = 15 to 22) and duration of immobilization was 56 min. (SD = 19.8, range = 42 to 70). In the summer, the 44 mg dose of xylazine HCl that was initially used appeared to produce a longer duration of immobilization (140 min.) than the 30 mg dose that was used later in that season (\bar{x} = 56 min, SD = 19.8).

Pregnant or lactating ewes exhibited similar response times to the immobilization process and immobilization did not apparently adversely affect gestation. Telazol® does cross the placental barrier (Telazol® product information leaflet) but two ewes that were immobilized in the beginning of the third trimester carried lambs to term.

One side effect was observed during the immobilization process. Seven sheep salivated copiously, but they did not appear negatively impacted due to excessive salivation as the pharyngeal-laryngeal reflexes were maintained.

Discussion

The physiological responses (respiration rate, heart rate, and rectal temperature) of the animals in our study appeared to be within an acceptable range for Bighorn Sheep. Our means are between the values reported for uncaptured Bighorn Sheep (Pond and O'Gara 1994) and for Bighorn Sheep captured with helicopters but presumed to be minimally stressed (Kock et al. 1987b).

To provide the most meaningful contrasts, we limited comparisons of this study's time responses and drug doses to studies where Rocky Mountain Bighorn Sheep were immobilized from the ground with other drug combinations. Times to induction in our study were between the induction times reported by Festa-Bianchet and Jorgenson (1985) for May–December (11.7 min, range = 3 to 46) and March–April (22.0 min, range = 6 to 51) when a combination of ketamine HCl and xylazine HCl was used. Duration of immobilization was longer than in Festa-Bianchet and Jorgenson (1985) when they stimulated the sheep to stand up (May–December: 53.3 min, range = 30 to 86, March–April: 37 min, range = 30 to 45). But their immobilization duration was up to three hours if the animal was left undisturbed. The use of xylazine HCl alone for immobilizing Rocky Mountain Bighorn Sheep from the ground by Jorgenson et al. (1990) resulted in shorter induction times (7.9 min, SE = 0.8, range = 3 to 16) than our study. Duration of immobilization was 32.3 min (SE = 3.6, range = 18 to 50) when the sheep were stimulated to stand up (Jorgenson et al. 1990). The shorter induction times in these studies (Festa-Bianchet and Jorgenson 1985; Jorgenson et al. 1990) in comparison to ours are likely a result of the greater amount of xylazine HCl used in those studies (Jorgenson et al. 1990).

Effective immobilization in our study required 30 mg of xylazine HCl in combination with 250 mg of

TABLE 2. Mean \pm SD time responses in minutes of Rocky Mountain Bighorn Sheep recorded during immobilization by Telazol® and xylazine HCl in Custer State Park, South Dakota between 1995 and 1998.

Time Responses ^a (minutes)	Telazol® and Xylazine HCl Concentrations (Total mg)		
	250:30	370:44	370:30
First Down	—	4	5.7 \pm 1.5
Still	11.6 \pm 3.7	9.5 \pm 3.5	10.7 \pm 6.1
Induction	20.4 \pm 6.0	21 \pm 2.8	19 \pm 3.6
Head Up	59	91	55 \pm 18.4
Walking	78.3 \pm 20.2	140	56 \pm 19.8
No Fall	127	140	216.5 \pm 4.9

^aFirst Down: time when the animal first laid on the ground

Still: time when the animal was recumbent and no longer moving

Induction: time when the animal was approached

Head Up: time when the animal first lifted its head

Walking: time when the animal first got up and walked

No Fall: time when the animal was able to maneuver without stumbling or falling

Telazol® in the winter and 370 mg of Telazol® in the summer based on a 60 kg ewe. This xylazine HCl dose is far less than has been reported in other studies where Bighorn Sheep were immobilized from the ground with xylazine HCl in combination with other drugs or alone. Xylazine HCl doses of 200 mg for June–December and 148 mg for March–April have been recommended in combination with 200 mg of ketamine HCl for 60 kg adult ewes (Festa-Bianchet and Jorgenson 1985). Jorgenson et al. (1990) reported 222 ± 6.6 mg of xylazine HCl for 60 kg adult ewes when used alone. In addition, an increase of only 14 mg of xylazine HCl in combination with 370 mg of Telazol® in our study appeared to dramatically increase the duration of immobilization. The total xylazine HCl dose was also important for satisfactory immobilization of Rocky Mountain Bighorn Sheep (Festa-Bianchet and Jorgenson 1985) and Roosevelt Elk (*C. e. roosevelti*) (Golightly and Hofstra 1989).

Similar to the Telazol® and xylazine HCl combination used in this study, xylazine HCl (Jorgenson et al. 1990) and ketamine HCl and xylazine HCl (Festa-Bianchet and Jorgenson 1985) also appear to have no effect on lambs during gestation and both studies observed excessive salivation in immobilized sheep.

Telazol® and xylazine HCl in combination offer many of the same advantages of ketamine HCl and xylazine HCl in combination including wide safety margins, rapid induction, ease of preparation, effective handling periods, and safety to handler (Kreeger 1997). An additional advantage of this combination may be the smaller doses of xylazine HCl necessary for successful immobilization in comparison to the combination of ketamine HCl and xylazine HCl and xylazine HCl alone. Smaller doses of xylazine HCl may reduce the effect of potential disadvantages associated with this sedative including extended recovery times, respiratory depression, and disruption of thermoregulatory capabilities (Kreeger 1997).

We conclude that the combination of Telazol® and xylazine HCl is a safe and effective means for immobilizing human-habituated, free-ranging adult Rocky Mountain Bighorn ewes from the ground. Based on a 60 kg ewe, we recommend using 250 mg of Telazol® (4.2 mg/kg) and 30 mg xylazine HCl (0.5 mg/kg) in winter and 370 mg of Telazol® (6.2 mg/kg) and 30 mg of xylazine HCl (0.5 mg/kg) in summer. Additional studies need to be conducted to investigate the safety and efficacy of this combination for other age and sex classes and with different capture techniques. The individual influence of Telazol® and xylazine HCl on time to induction and immobilization duration should also be explored; observations during this study suggest that the Telazol® dose may have a greater influence on induction time while xylazine HCl appeared to be the more influential drug component on immobilization duration. Last, the potential to reverse the

xylazine HCl component in the Telazol® and xylazine HCl combination (Millsbaugh et al. 1995) should be investigated.

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Status, Distribution, and Biology of the Mountain Beaver, *Aplodontia rufa*, in Canada

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The distribution and status of the Mountain Beaver, *Aplodontia rufa*, in Canada is reviewed, based on museum specimens, published and unpublished sources, other collected observations, and on sign surveys conducted from 1996 to 1998 east of the Cascade Mountain divide. Biological information presented from the sign surveys includes densities of nest sites, habitat parameters, the diet based on plants found in haypiles outside nest sites, and the effects of clearcutting on Mountain Beaver. In Canada, Mountain Beavers are limited to extreme southwestern British Columbia because the Fraser River is an effective barrier to northward dispersal along the Coast Mountains, and because climates become too dry to support Mountain Beavers east and north of the Cascade Mountains. Typical habitat on the east side of the Cascade Mountains consists of sites with damp soils, often near streams, at elevations between 1200 and 1800 m. Principal summer food species found in haypiles within forests were Sitka Valerian (*Valeriana sitchensis*), Horsetail (*Equisetum* spp.), Twisted Stalk (*Streptopus* spp.), Thimbleberry (*Rubus parviflorus*), and Cow-parsnip (*Heracleum lanatum*). Narrow-leaved Fireweed (*Epilobium angustifolium*) was the most common food in haypiles in clearcuts. Densities of underground nest sites in small (< 2.5 ha) areas of high quality habitat reached up to 5.8 nests/ha. Densities over large areas where high habitat quality was relatively widespread averaged 35.3 nests/km². Where high quality habitat was not as widespread, densities averaged only 5.9 nests/km². Very low densities of 2 nests/km² were found where the heavy machinery associated with clearcutting and the site preparations for planting had severely disturbed the soil layer while 42 nests/km² were found where logging had been conducted in similar areas but without soil disturbance. The status of the Mountain Beaver in Canada is considered vulnerable because the range appears to be contracting in the lower Fraser River valley due to habitat lost to urbanization and agriculture, and because of its susceptibility to intensive forestry operations elsewhere in its range in Canada.

Key Words: Mountain Beaver, *Aplodontia rufa*, status, distribution, habitat, British Columbia.

The status of the Mountain Beaver, *Aplodontia rufa*, in Canada was first evaluated by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1984 where it was assigned the Not At Risk designation because there was insufficient data available to place it in any other category (Orchard 1984*). A considerable amount of new data on its habitat and distribution is now available from extensive Mountain Beaver surveys undertaken from 1996 to 1998 east of the crest of the Cascade Mountains under the auspices of the British Columbia Ministry of Environment, Lands and Parks (Gyug 1996*; Gyug 1997*; Gyug 1998*). In 1999 COSEWIC designated the Mountain Beaver as vulnerable in Canada on the basis of this new information as well as a review of other information as presented in an updated status report (Gyug 1999*) from which some of this paper has been drawn.

The Mountain Beaver is the only living member of its family, Aplodontidae, as well as the most primitive living rodent as it is the only living species of the Protrogomorpha, the group to which the earliest known rodents belonged (Hall 1981). It is a small

to medium-sized semifossorial rodent with a thick, heavy body covered with coarse, dull dark brown fur (Carraway and Verts 1993). The recorded body weights of two adult museum specimens from British Columbia were 1.13 and 1.25 kg. The range in total length of adult museum specimens from British Columbia is between 315 and 470 mm of which 18–68 mm is made up of the tail (Cosco 1980*; and from list of museum specimens).

Mountain Beavers have a very primitive renal anatomy that cannot produce hypertonic urine (Nungesser and Pfeiffer 1965). Therefore they must consume large amounts of water, either directly or in their food, and this also limits them to living in areas with a cool and humid microclimate (Carraway and Verts 1993). Mountain Beavers occur in forested areas throughout their range, often preferring early to mid-seral stages with specific requirements for deep soils that allow tunnel and nest construction, for cool and moist microclimates within tunnels (Carraway and Verts 1993), and for suitable forage within 50 m (Martin 1971).

The family Aplodontidae arose in western North America, with all subsequent speciation of the family to the present in the westcentral portion of the continent (Shotwell 1958). Currently, Mountain Beavers are only found within and to the west of the

*See Documents Cited section.

Cascade and Sierra Nevada mountain ranges of western North America (Hall 1981). There are two recognized subspecies in Canada (Hall 1981). *A. rufa rufa* (Rafinesque, 1817) is found south of the Fraser River from Hope to Langley. *A. rufa rainieri* Merriam, 1899 is found east of Hope, north along the Cascade Mountains to approximately Lytton and Merritt, and west approximately to Princeton. The *rufa* subspecies is ranked provincially by the British Columbia Conservation Data Centre as "critically imperiled, or imperiled" while the *rainieri* subspecies is ranked as "vulnerable".

Study Area and Methods

The distribution of Mountain Beavers in Canada was determined based on published and unpublished sources, on collection locations of Mountain Beaver specimens in North American museums from data provided by David Nagorsen of the Royal British Columbia Museum, on location data from surveys conducted from 1996–1998 on the east side of the Cascade Mountain divide as described below, and on a few observations of my own or from others west of the Cascade Mountain divide.

The major biogeoclimatic zones (Green et al. 1984; Lloyd et al. 1990) within the range of the Mountain Beaver in Canada are: the Coastal Western Hemlock zone at low elevations to the west of the Cascade Mountains, the Mountain Hemlock zone at higher elevations on the west side of the Cascade Mountain divide, the Engelmann Spruce-Subalpine Fir zone at higher elevations on the east side of the Cascade Mountain divide, the Montane Spruce zone at mid-elevations on the east side of the Cascade Mountains, and the Interior Douglas-fir zone at lower elevations on the east side of the Cascade Mountains. The Interior Douglas-fir zone is also found in some drier areas in local rain shadows on the western side of the Cascade Mountains. The Cascade Mountain divide reaches heights up to 2400 m with treeless alpine zones and subalpine parkland zones occurring above 1700 m in wetter areas, and 1900 m in drier areas.

Based on 30-year normals from 1961–1990 (Atmospheric Environment Service 1993), the climate of the area could best be described as wet and mild at low elevations on the windward or west side of the Cascade divide (Chilliwack, elevation 11 m, annual precipitation of 1850 mm with 6.7% falling as snow) and as drier and cooler at low elevations on the lee or east side of the Cascade divide (Princeton, elevation 700 m, annual precipitation of 343 mm with 44% falling as snow). The northern end of the Mountain Beaver range is also dry and cooler since it is in the lee of the Coast Mountains (Lytton, elevation 258 m, annual precipitation of 423 mm with 30% falling as snow; Merritt, elevation 588 m, annual precipitation of 311 mm with 28% falling as snow).

From 1996 to 1998, surveys for Mountain Beavers were undertaken in areas proposed for timber harvest on Five-year Forest Development Plans on the east side of the Cascade Mountains within or near to the known range of Mountain Beavers as described in Cowan and Guiguet (1965). Within these selected areas, searches were conducted for Mountain Beaver sign concentrating on wet forested or semi-forested sites such as stream courses, seepage channels, alluvial fans and seepage slopes that could be identified on 1:15 000 colour aerial photographs.

Sign surveys were relied on to detect the presence of Mountain Beavers since they are largely nocturnal and typically forage above ground for less than 2 hours per 24-hour period (Voth 1968*). The types of tunnel and runway systems made by Mountain Beavers are different from those of any other fossorial or semi-fossorial mammal occurring within the study area. Burrows, tunnels and runways 15–20 cm in diameter or width radiate into wet areas or to sites with herbaceous forage from an underground nest site that is above the water table. Occupied nest sites were recognized during the summer by piles of fresh or wilting green vegetation piled outside burrow entrances. As this green vegetation wilts, it is taken underground (Wallis 1946*) where it is eaten almost immediately, since it will quickly rot in the near 100% humidity of the burrows (Voth 1968*). These "haypiles" are not used for curing hay in the same sense that pikas, *Ochotona princeps*, will rely on dried and stored vegetation for winter food. In 1996 and early 1997, we listed the plants that occurred within each Mountain Beaver haypile found to help determine Mountain Beaver diet in the Cascade Range of British Columbia.

In high quality habitat Mountain Beavers often occur at high densities which are loosely referred to as colonies (Carraway and Verts 1993). However, these are actually aggregations of solitary adults living within their own territories of 0.03 to 0.2 ha (Martin 1971). At each site we attempted to count the number of occupied nests. Since adult or independent subadult Mountain Beavers will nest within about 20 m of each other (Martin 1971), we interpreted large fresh haypiles found beside deep burrows as individually occupied nest sites only when the haypiles were separated by more than 20 m from each other. We often found smaller haypiles close to these larger haypiles since Mountain Beavers will often bring fresh forage closer to the nest site on a relay-type basis (Voth 1968*). Nest sites may have been occupied by adult females with young rather than by solitary Mountain Beavers, but there are no reproductive data available for any Canadian populations so it is not known during what range of dates the dispersal of young takes place. It is assumed that these populations are similar to populations in the

United States where there is one litter per year, typically of two or three, the young emerge from the burrow at two-and-a-half months of age (Feldhamer and Rochelle 1982), and then move away from the natal site soon after emerging sometime between June and September to establish their own nests (Martin 1971).

The location of each Mountain Beaver nest site with fresh sign of burrowing or haypiling was recorded on a large-scale map (1:5 000 to 1:20 000 scale) with assistance from handheld GPS units or 1:15 000 colour aerial photographs to improve mapping accuracy. Large-scale maps of every Mountain Beaver location from the 1996–1998 surveys are provided in Gyug (1996*), Gyug (1997*) and Gyug (1998*). Elevation, aspect, slope, and soil moisture were recorded at most sites. The type of water drainage (e.g., stream, seep or receiving site) that each nest site was near was recorded. In 1997 bank-full stream width was recorded when the nest site was found close to a permanent stream.

A complete census of nest sites was attempted within areas in the Champion Creek drainage (a tributary of the Tulameen River) to determine if Mountain Beaver occupied clearcuts, and whether that occupation depended on the type of harvesting methods or silvicultural treatments used. A 1255-ha contiguous portion of the Champion Creek drainage where 28% of the area had been clearcut in the previous 8 years was censused in 1997. On average 80 ha were censused in one day by each person including a search of all stream courses and wet sites, and of many upland areas between the wet sites. Smaller areas of 40, 31.5 and 23 ha were also censused in the Champion Creek drainage. The exact location of each Mountain Beaver nest was recorded as being within forest or clearcut, and if in a clearcut, the type of tree felling, log yarding and site preparation methods used. Additional censuses used for density comparisons were conducted in a 900-ha forested area at the head of the Tulameen River in three separate visits from 1996 to 1998, and in four proposed cutblocks in the Railroad Creek drainage (a tributary of the Tulameen River) in 1997 and 1998.

Results

Distribution

In Canada, the Mountain Beaver is found only in the extreme southwest portion of British Columbia where its total range of about 10 000 km² occupies about 1% of the total area of British Columbia. This is based on 635 nest sites found in the 1996–1998 surveys east of the Cascade Mountain divide, 136 museum specimens and 24 other observations (Figure 1). Some of the locations of museum specimens as recorded on the museum labels were not very precise or used local names that have since fall-

en into disuse but most locations could be determined fairly accurately. 99.5% of the 635 locations of Mountain Beavers found during the 1996–1998 surveys east of the Cascade Mountain divide were within 21 km of the divide.

The limital records of Mountain Beaver range in Canada are from museum specimen records. The vicinity of the northernmost record from 1947 (locality 1 on Figure 1A and in Appendix 1) is not known exactly since the museum specimen location was only recorded as “13 miles northeast of Canford”. We visited this vicinity on both 8 September and 1 October 1998, and found small fresh piles of green vegetation typical of Mountain Beaver in only one location (50° 15' 10"N, 120° 48' 00"W) beside Steffens Creek, 1.2 km above its confluence with Hector Creek. However, we found no sign of burrowing typical of Mountain Beaver at that location and could not locate a nest site, so that this particular spot may have been only temporarily, or else very recently, occupied by Mountain Beaver.

The vicinity of the easternmost record (locality 2 on Figure 1A) collected in 1928 is provided fairly accurately and is near the confluence of Whistle (formerly Stirling) Creek and the Similkameen River. The lowest 4 km of Whistle Creek was searched in 1998 with no trace of any Mountain Beaver sign. In 1997, I found a single occupied Mountain Beaver nest at the height-of-land 19 km southwest of this point, which may now be the most eastward occurring Mountain Beaver in the present range.

The westernmost historical record is from Langley (locality 27 on Figure 1A) collected in 1969. However, the exact collection location of this specimen is not specified. “Langley” could refer to the City of Langley as shown on Figure 1A, but is locally used to refer to the entire rural area within 5 km to the west, and 10–15 km to the south, east and north. Cosco (1980*) could find no Mountain Beaver sign anywhere in that area. The westernmost area known to be occupied in 1979 was the western end of Sumas Mountain about 30 km east of the City of Langley (Cosco 1980*). The westernmost area known to be occupied at present is near the summit of Sumas Mountain about 38 km east of the City of Langley (Johanna Saaltink, personal communication).

There is one unconfirmed report of Mountain Beaver burrows being found west of Stave Lake approximately 10 to 20 km north of the Fraser River (Glen Ryder, cited in Cosco 1980*). Cosco (1980*) searched unsuccessfully for Mountain Beaver sign north of the Fraser River in several areas. If this report of Mountain Beavers is correct, it may have been from a single individual that dispersed northwards across the Fraser River from the Sumas Mountain area near Chilliwack since there do not appear to be any populations of Mountain Beaver north of the Fraser River.

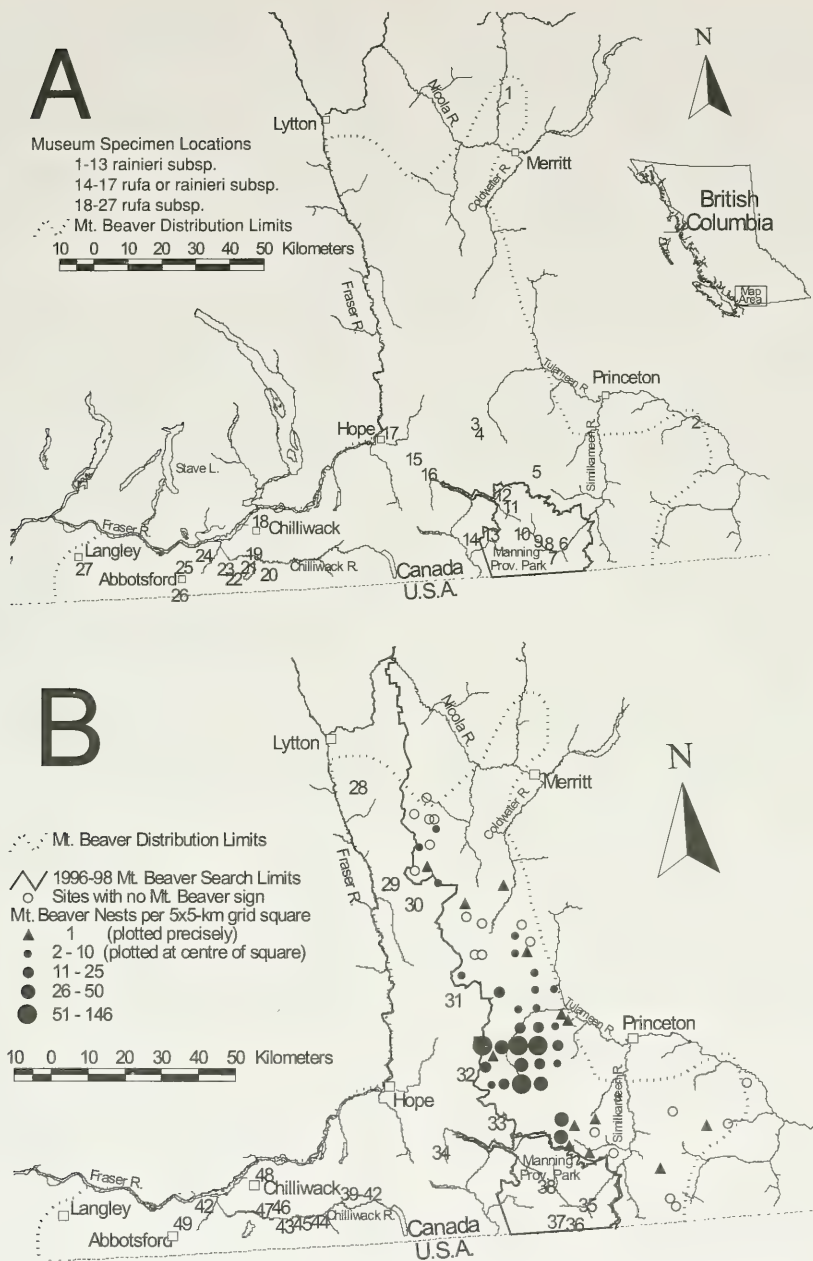


FIGURE 1. Distribution of Mountain Beaver in Canada based on (A) museum specimens with numbered locations keyed to data in Appendix 1, and (B) Mountain Beaver occupied nest surveys (N = 635 nests) undertaken for British Columbia Ministry of Environment, Lands and Parks from 1996–1998 east of the Cascade Mountain divide, as well as other Mountain Beaver observations west of the divide and in Manning Provincial Park, with numbered locations keyed to data in Appendix 2.

A series of notes and letters in the *B.C. Naturalist* (Keen 1996; Lawrence 1996; Sampson 1996) reported Mountain Beaver sightings that, if confirmed,

would have extended the known range of Mountain Beavers northward by about 1000 km. David Nagorsen of the Royal British Columbia Museum

(personal communication) has examined a purported Mountain Beaver specimen from the Glenora site near Telegraph Creek in northern British Columbia and has found it to be a Woodchuck, *Marmota monax*. I suspect the other sightings were also of Woodchucks as this species will sometimes live in dense forests in the wet belts of British Columbia where few people expect to see them; they are approximately the same size as Mountain Beavers; and they are often completely black, dark grey or dark brown in colour like Mountain Beavers.

Population Densities and Trends

Population densities in Canada are only available from the censuses conducted in a few areas on the east side of the Cascade Mountains. After the Champion Creek nest site censuses, it became clear that Mountain Beaver densities did vary with general wetness of the terrain, so I subdivided the main 1255-ha census area in Champion Creek into two smaller areas (Table 1). In relatively high quality Mountain Beaver habitat for the survey area, where seepage water at the surface was fairly widespread, overall densities were much higher (35.3 nest sites/km²) than in lower quality habitat that was drier (5.9 nest sites/km²). Local densities in small completely occupied sites within the larger areas was 4.4 and 5.8 nests/ha (equivalent to 440 and 580 nests/km²) in two hummocky complexes of forest and wet meadows that received moisture from higher upslope. However, these high densities never occurred over areas larger than 2.5 ha so that overall densities in Table 1 were much lower.

The only historical evidence of a change for any Canadian population of Mountain Beavers is in the lower Fraser Valley in the vicinity of Chilliwack and Abbotsford. Numbers appear to be decreasing and range probably contracting although no quantitative

or thorough inventories have ever been undertaken in that area. Lord (1866) found numerous Mountain Beaver living along the lower Chilliwack and Sumas Rivers in the Fraser Valley lowlands. Fannin (1893) was aware of Lord's sightings but could not confirm them since the people of Chilliwack of whom he enquired had never seen or heard of Mountain Beavers. Streater (1895*) did not encounter, nor hear of, any Mountain Beaver in the Fraser Valley lowlands. Brooks (1902) noted that it was very rarely seen in the Fraser Valley lowlands although they were common in the foothills. Laing (1927*) collected Mountain Beaver at Huntingdon in the Fraser Valley lowlands where he considered them uncommon but present in the banks of drainage ditches that held permanent water. He indicated that the numbers of Mountain Beaver had probably been reduced in this area by the conversion of the area to agricultural fields even at that time, although occasional museum specimens continued to be taken from that location up until 1952. Dennis Knopf (personal communication) recalled Mountain Beaver being very uncommon on agricultural lands on the valley floor in the 1950s and 1960s with the odd animal reported probably being a dispersing individual from populations on the hills in and around the valley. He also recalled that older farmers remembered a time when Mountain Beavers did occur in some places in the valley bottom and were considered agricultural pests. No populations of Mountain Beavers are currently known on the Fraser Valley lowlands.

It appears that Mountain Beaver may also be declining in numbers on the forested low hills in and around the lower Fraser Valley, even on non-agricultural lands. They no longer occur on Mount Shannon (an isolated hill in the Fraser Valley lowlands at Chilliwack), and very few individuals still appear to

TABLE 1. Mountain Beaver densities in censused areas of the Tulameen River drainage, British Columbia, between 1996 and 1998.

Area Name	Relative Habitat Quality	Area (ha)	Number Occupied Mountain Beaver Nests	Mountain Beaver Nest Density (per km ²)
Champion Creek, South Area	Low	789	52	6.6
Upper Tulameen	Low	900	47	5.2
Total	Low	1689	99	5.9
Champion Creek, North Area	High	466	113	24.2
Champion Creek, TSL A42316 ¹	High	31.5	11	34.9
Champion Creek, CP 132-6 ²	High	23	7	30.4
Champion Creek, CP 120-5 ³	High	40	14	35.0
Railroad Creek ⁴	High	71.1	78	109.7
Total	High	631.6	223	35.3

¹Merritt Forest District, Small Business Forest Enterprise Program, Timber Sale Licence A42316, logged in 1988
²Tolko Industries, Proposed Cutting Permit 132-6
³Tolko Industries, Cutting Permit 120-5, logged in 1989
⁴Merritt Forest District, Small Business Forest Enterprise Program, Proposed Timber Sale Licences A42313-1, A42312-1, A50518-1 and A50518-2

live in the Mount Tom and Ryder Lake area in the foothills south of Chilliwack where there were once thriving populations (Dennis Knopf, personal communication). There is still a small population on Sumas Mountain, an isolated hill rising in the Fraser Valley lowlands at Abbotsford, which appears to be isolated by at least 6 km from the next nearest population to the south on Vedder Mountain in the Fraser Valley foothills (Johanna Saaltink, personal communication).

Habitat

Subsurface drainage that keeps the majority of the tunnels and runways wet, even to the point of having water trickling or flowing through them, was very characteristic of sites occupied by Mountain Beaver on the east side of the Cascade Mountains of British Columbia (Table 2). However, underground nest sites must still be dry and above the water table. Highly preferred habitat can best be described as mosaics of wet meadows and upland areas, as seepage zones on hillsides, or as the banks of very small streams. Mountain Beaver nests were almost invariably found under large trees, large stumps or large logs. Mountain Beaver habitat in Canada does not appear to be different from the descriptions of typical Mountain Beaver habitat throughout their range (Carraway and Verts 1993).

Forty-five per cent of Mountain Beaver nests were found in or near to wet areas, ephemeral streams, permanent streams or other drainage features that were too small to be mapped at the 1:20 000 scale (Table 2). The remainder that were found within 50 m of mapped streams mostly occurred along smaller seeps or very small streams where they entered the larger stream gullies, or where these smaller drainage features joined the larger stream. Fewer and fewer nests were found near to streams as stream order increased (Table 2). Bank-full stream widths were only measured at 148 of the nest sites but were on the order of 0.5 to 2.5 m for first-order streams, 1 to 5 m for second-order streams, 2 to 7 m for third-order streams and 10 to 15 m for fourth-order streams. Nests were never found in the gravel or cobble floodplains of larger streams or rivers.

Almost all Mountain Beaver nests were found between 1200 and 1800 m (Table 2). 94.7% of the 635 Mountain Beaver nests were found in the Engelmann Spruce-Subalpine Fir zone. Two to three times more nests were found on cool, or north-facing, aspects only when nest sites were near unmapped small drainages or on first-order streams (Table 3). On second to fourth-order streams that usually had pronounced deep gullies, there was no preference for either cool or warm aspects. Mountain Beaver nests were commonly found on slopes up to 45% with the highest proportion (53%) found on moderate slopes of 10–25% (Table 3).

Diet

The items occurring most commonly in Mountain Beaver haypiles on the east side of the Cascade Mountains in British Columbia were Sitka Valerian (*Valeriana sitchensis*), Horsetail (*Equisetum* spp.), Twisted Stalk (*Streptopus* spp.), Thimbleberry (*Rubus parviflorus*), and Cow-parsnip (*Heracleum lanatum*) (Table 4). Narrow-leaved Fireweed (*Epilobium angustifolium*) appeared to be a preferred item where it was available. It was abundant in haypiles found in forested areas only when the haypile was within 50 m of a clearcut, which accounted for almost all the Narrow-leaved Fireweed found in haypiles in forests (Table 4). Narrow-leaved Fireweed dominated all Mountain Beaver haypiles found in clearcuts.

Winter diet is necessarily different from the summer diet because most herbaceous forage species will have died back for the 6 to 8 months of the year that snow lies on the ground in the Cascade Mountains. Extensive clipping of White-flowered Rhododendron, *Rhododendron albiflorum*, shrubs was seen near nest sites, sometimes at ground level, but often 1 m up on the stem. This clipping was probably being done by Mountain Beavers under the snow in winter since White-flowered Rhododendron was only found in 3.8% of summer haypiles, and, in my experience, no other mammal occurring in the area browses on it. Clipping high up on the stems was probably occurring when stems were pressed to the ground by snow.

TABLE 2. The nearest type of drainage system as mapped at 1:20 000 scale, the soil moisture regime of Mountain Beaver tunnel/runway systems, and the elevation of occupied Mountain Beaver nests found east of the Cascade Mountain divide in British Columbia from 1996–1998.

Nearest Drainage System or Stream	% (N=511)	Soil Moisture Regime*	% (N=526)	Elevation (m)	% (N=583)
Not on a continuous drainage	5.9	Mesic	2.9	800–1000	0.3
Unmapped small stream/seep	38.9	Subhygric	21.1	1001–1200	2.4
Within 50m of 1st order stream	26.2	Subhygric/Hygric	23.4	1201–1400	26.6
Within 50m of 2nd order stream	15.5	Hygric	27.2	1401–1600	46.1
Within 50m of 3rd order stream	11.9	Hygric/subhydric	14.1	1601–1800	24.3
Within 50m of 4th order stream	1.6	Subhydric or wetter	11.4	1801–2000	0.2

*subhydric indicates a water table < 30 cm from surface with hygric and subhygric progressively drier to mesic (normal) levels of soil moisture (Lloyd et al. 1990).

TABLE 3. Slope and aspect of occupied Mountain Beaver nests found east of the Cascade Mountain divide in British Columbia from 1996-1998 in relation to distance from stream and order of stream as mapped at 1:20 000 scale.

Stream Type	Slope (%)	Warm Aspects (136°-285°)	Cool Aspects (286°-135°)
> 50 m from a mapped stream	0-9	6	18
	10-25	32	81
	26-45	23	46
	46-70	4	9
	>70	0	1
	Total	65	155
Within 50 m of a 1st order stream	0-9	0	13
	10-25	26	57
	26-45	6	17
	46-70	1	3
	>70	0	1
	Total	33	91
Within 50 m of a 2nd to 4th order stream	0-9	16	16
	10-25	24	29
	26-45	13	10
	46-70	11	6
	>70	1	0
	Total	65	61

Effects of Clearcutting

In the censused areas of the Champion Creek drainage of the Tulameen River system, Mountain Beavers occupied clearcuts (31 of 197 nests) but densities were highly dependent on the type of tree felling, the type of log yarding and the post-logging site preparation or silvicultural treatments (Table 5). Streams or wet areas within clearcuts that had been highly impacted by machinery during logging or site preparation were almost completely unoccupied by Mountain Beavers with densities of only 2.0 nests/km². Density of Mountain Beaver nests was higher when even buffers of as little as 5 m within either side of a stream had been avoided by heavy machinery during logging. Where there was very little ground disturbance during logging, i.e., trees had been hand-felled with chainsaws, and then logs had been helicopter yarded or ground skidded over very deep snow, densities were very high at 42.4 nests/km².

Discussion

Distribution

It would appear that Mountain Beavers are not strong dispersers since the Fraser River seems to have formed an insurmountable obstacle to northward dispersal into what appears to be otherwise suitable habitat. In the eastern and northern parts of the range, Mountain Beaver nests became uncommon and were found in fewer and fewer areas of otherwise apparently suitable habitat as the limits of the range were approached. While I have provided a line

as the distribution limit of the Mountain Beaver in Figure 1, the line is only definitive where the Fraser River forms a distinct boundary to the range. There is always the possibility that dispersing individuals will establish in gullies or wet areas outside this mapped distribution limit. However, the likelihood of establishing large populations outside these limits would appear to be low because the interior of British Columbia in the rain shadow of the Coast and Cascade Mountains is too dry and is probably physiologically limiting to Mountain Beavers.

Most of the recent records in Canada are based on sign only, so that no new information on the location of the boundary between the two subspecies is available. However, museum specimens along a zone containing localities 14-17 of Figure 1A have been labeled variously as either the *rufa* or the *rainieri* subspecies so that this is the probably at or near the boundary. Cosco (1980*) examined the museum specimens from the Royal British Columbia Museum and the University of British Columbia, and, based on locality alone, considered any specimens labelled as the *rufa* subspecies from localities 14-17 to actually be *rainieri*. He put the subspecies boundary just to the west of that area, in a location where no specimens have ever been collected. Within the specimens he examined, the *rainieri* subspecies averaged larger than *rufa* in all cranial measurements but there was also some overlap in each measurement as well. The collection of additional specimens in the area just to the west of localities 14-17 combined with a re-examination of existing

TABLE 4. Freshly clipped vegetation items found in > 5% of 160 Mountain Beaver haypiles in mature forests in the eastern Cascade Mountains of British Columbia in 1996 and 1997.

Species or Taxon	Scientific Name	Frequency (% of haypiles containing species)
Sitka Valerian	<i>Valeriana sitchensis</i>	73
Horsetail	<i>Equisetum</i> spp.	57
Twisted Stalk	<i>Streptopus</i> spp.	47
Thimbleberry	<i>Rubus parviflorus</i>	37
Cow-parsnip	<i>Heracleum lanatum</i>	34
Black Huckleberry	<i>Vaccinium membranaceum</i>	33
Indian Hellebore	<i>Veratrum viride</i>	25
Oak Fern	<i>Gymnocarpium dryopteris</i>	24
Fairybells	<i>Disporum</i> spp.	22
Arrow-leaved Groundsel	<i>Senecio triangularis</i>	21
Alder	<i>Alnus</i> spp.	18
Grasses	<i>Poaceae</i>	18
Foamflower	<i>Tiarella</i> spp.	16
Black Twinberry	<i>Lonicera involucrata</i>	15
Meadow Rue	<i>Thalictrum occidentale</i>	15
Narrow-leaved Fireweed	<i>Epilobium angustifolium</i>	14
Arctic Lupine	<i>Lupinus arcticus</i>	14
Mountain Ash	<i>Sorbus sitchensis</i>	13
Arnica	<i>Arnica</i> spp.	11
Bunchberry	<i>Cornus canadensis</i>	10
Queen's Cup	<i>Clintonia uniflora</i>	10
Utah Honeysuckle	<i>Lonicera utahensis</i>	10
Black Gooseberry	<i>Ribes lacustre</i>	8
False Solomon's Seal	<i>Smilacina racemosa</i>	8
Baneberry	<i>Actaea rubra</i>	7
Oval-leaved Blueberry	<i>Vaccinium ovalifolium</i>	7
Willow	<i>Salix</i> spp.	7
Bog-orchid	<i>Habenaria</i> spp.	6

specimens would probably be required to clarify the nature and location of the subspecies boundary.

Population Densities and Trends

The densities in the small areas of very high quality habitat reported here appear similar to typical densities reported in the coastal ranges of Oregon (range of 2-20/ha in review by Verts and Carraway 1998) and coastal Washington (3.2-3.8/ha, Neal and Borrecco 1981). However, overall densities, even in areas of relatively high-quality habitat for the eastern

side of the Cascade Mountains in British Columbia, are 10-times lower than these maximum densities because maximum densities only occur in very small areas up to about 2.5 ha in size.

In the lower elevations of the Fraser River valley, habitat loss through urbanization and agriculture is probably the major cause of downward trends in Mountain Beaver populations. Areas that they previously occupied on the valley floor of the lower Fraser valley now appear to be devoid of Mountain Beavers.

TABLE 5. Mountain Beaver densities in clearcuts in the Champion Creek drainage, British Columbia, in relation to the type of tree felling, log yarding, and stream treatments.

Tree Felling Method	Log Yarding Method	Stream Treatment	No. of Clearcuts	Total Area (ha)	Number Mountain Beaver Nests	Mountain Beaver Density (per km ²)
Hand ¹	Helicopter, or Ground Skidding on deep snow		4	40.1	17	42.4
Hand ¹	Cable Yarding		2	21.4	3	14.0
Machine ²	Ground Skidding	Machine Buffered	4	108.9	8	7.4
Machine ²	Ground Skidding	No Buffers	7	145.3	3	2.0

¹chain saws used to fell trees

²excavator-type feller-buncher used to fell trees

In the Chilliwack and Abbotsford areas of the lower Fraser Valley, suburban development is now focusing on private land holdings in the foothill areas where Mountain Beavers were previously abundant. This is because valley bottom areas are already highly developed, are very expensive closer to Vancouver, or have been frozen into agricultural status by British Columbia's Agricultural Land Reserve.

Diet

Diet in this study was found to be more similar to that at high elevations in the Cascade Mountains such as Crater Lake in Oregon than to coastal forests. At Crater Lake the principal species found in Mountain Beaver haypiles were Bleeding Heart (*Dicentra formosa*), Sitka Valerian (*Valeriana sitchensis*) and Fat Solomon (*Smilacina amplexicaulis*) (Wallis 1946*). In coastal forests, Sword Fern (*Polystichum munitum*) and Bracken Fern (*Pteridium aquilinum*) appear to constitute a large portion of the Mountain Beaver's diet in most studies (see Carraway and Verts 1993). On the east side of the Cascade Mountains in Washington State, Stagg (1997*) found that Bracken Fern was a highly preferred food wherever it occurred, and was one of only four species along with Starry False Solomon's Seal (*Smilacina stellata*), Vanilla Leaf (*Achlys triphylla*) and Narrow-leaved Fireweed found to comprise more than 10% of haypiles. Clearly, where Bracken Fern and Sword Fern are not available, Mountain Beavers will forage on other species.

While we did not quantitatively measure the amount of vegetation in Mountain Beaver haypiles in the Cascade Mountains, the size was highly variable and seemed to depend on the weather. In the cool and wet summers of 1996 and 1997, haypiles tended to be very large and obvious with the largest haypile found completely covering an area of forest floor 5-m in diameter. In the very hot and dry summer of 1998, haypiles were very small and often more difficult to find, typically consisting of only a few bundles, where each bundle is one mouthful brought in to the pile (Voth 1968*). The number of stems brought in per night can be considerable as Wallis (1946*) found that one Mountain Beaver studied for a 16-day period brought in an average of 203 stems each night. Individual stems only remained in the piles until they wilted, and were then brought underground to eat. I suspect that in our study area in 1998 the piled herbaceous stems wilted and became suitable for eating much more quickly than in 1996 or 1997. The residency time of stems in the piles was probably much shorter in 1998 so that overall size of piles was much smaller.

Effects of Clearcutting

Within their present range in the Cascade Mountains in British Columbia, clearcutting and

associated silvicultural practices are probably the major limiting factors preventing Mountain Beavers from using what might be otherwise suitable habitat. Based on the correlation of low densities with soil-disturbing logging practices, these practices appear to be extremely damaging to Mountain Beaver populations on the east side of the Cascade Mountains probably through direct mortality and by limiting the recolonization opportunities after clearcutting.

Clearcutting on the east side of the Cascade Mountains is typically accompanied by extensive mechanical soil disturbance by heavy machinery cutting and hauling trees to yarding sites as well as during preparation of the cutover areas for planting. After clearcutting, bulldozers and excavators are typically used to pile logging slash to allow it to be burned. The wet forest sites favoured by Mountain Beavers in the Cascade Mountains are often ditched using excavators to allow excess moisture to drain and lower the water table so tree seedlings can be more successfully planted. Some of the wettest sites in clearcuts are dug up by excavators to create mounds as planting sites for seedlings. Forest licensees are continually seeking to extract more economic gain from the forest base and timber harvesting and road building is proceeding to encompass most of the available land base. The effects of these forest practices on Mountain Beaver can only increase in British Columbia as high intensity forest management increases.

The negative effects of clearcutting found in this study may not extend to the wet low-elevation coastal forests of Washington and Oregon where Mountain Beavers seem to readily reoccupy sites after clearcutting (e.g., Hacker and Coblenz 1993). It could be that forage and shrub cover grows more quickly and at higher densities in coastal areas after clearcutting. It is possible that soils are generally deeper, more friable and wetter in coastal areas and therefore new nest sites are more easily established after disturbances. Also, Mountain Beaver densities in general may be much higher in coastal areas and these larger populations may provide a larger pool of potential immigrants for vacated sites than are available at higher elevations on the dry side of the Cascade Mountains.

Status

Aplodontia rufa rufa is ranked by the British Columbia Conservation Data Center (CDC) globally as "secure?", provincially as "critically imperiled, or imperiled", and is on the provincial Red (Threatened/Endangered) List of British Columbia's Ministry of Environment, Lands and Parks. *Aplodontia rufa rainieri* is ranked by the British Columbia CDC globally as "secure?", provincially as vulnerable, and is on the Blue (Sensitive/Vulnerable) List of British Columbia's Ministry of Environment, Lands and Parks.

The Mountain Beaver is one of a group of Pacific Northwest land mammal species that reaches its northern limits on the mainland of southwestern British Columbia, and are found nowhere else in Canada (Cowan and Guiguet 1965). Included in this group are two shrews, three moles, five rodents and the Western Spotted Skunk, *Spilogale gracilis*. Of this group, the Pacific Water Shrew, *Sorex bendirii*, and Townsend's Mole, *Scapanus townsendii*, have been designated as threatened in Canada by COSEWIC.

All native terrestrial vertebrates are recognized as wildlife under the Wildlife Act of 1996 in British Columbia and as such are considered to be owned by the provincial Crown, and can only be killed under permit. However, the Wildlife Act is usually not applied to industrial forestry operations that, as a side effect, will kill smaller species of wildlife that may include Mountain Beavers. In Washington and Oregon, the Mountain Beaver is considered a forest pest in Douglas-fir plantations because of its use of young Douglas-fir as a forage species up to four years after planting (Borrecco et al. 1979). Up to 25% of newly planted Douglas-fir seedlings can be lost to Mountain Beavers (Hooven 1977). Borrecco et al. (1979) reported that damage was occurring on 1110 km² of forest land in Washington, Oregon and northern California. Douglas-fir generally does not occur in the higher elevation areas where Mountain Beavers were found on the east side of the Cascade Mountains in British Columbia, although Douglas-fir is common at lower elevations on the west side of the Cascade Mountains. Minor instances of Mountain Beaver damage were noted in a few British Columbia conifer plantations in the Chilliwack Valley by Cosco (1980*) although he concluded that damage was minimal and no direct controls were required.

Approximately 13% (1330 km²) of the Mountain Beaver's Canadian range is in seven parks, recreation areas, or ecological reserves that are protected from industrial resource extraction. Outside of these protected areas, Mountain Beavers have been designated as "Identified Wildlife" within measures set out under the regulations of the Forest Practices Code of British Columbia Act (British Columbia Ministry of Forests and Ministry of Environment, Lands and Parks 1999). There are now special forest management practices designed to maintain populations of this species. However, these practices will only be applied within designated Wildlife Habitat Areas, none of which have yet been set aside for Mountain Beavers, and whose designation will be subject to economic as well as other considerations.

Outside of Canada, the Point Arena subspecies (*A. rufa nigra*) has been federally listed as endangered in the United States since 1991 (U.S. Fish and Wildlife Service 1998*). There are estimated to be 200 to 500

Point Arena Mountain Beavers in an area of 62 km² in Mendocino County in northern California. This population is small and completely isolated from other Mountain Beaver populations. Threats to this population have been identified as: alteration of natural habitat caused by urban development, timber harvesting and agricultural practices; brush clearing; predation by domestic cats and dogs; and rodent control measures intended for other species.

The International Union for Conservation of Nature and Natural Resources (IUCN) ranks the Mountain Beaver overall as "Lower Risk, near threatened" (Hafner et al. 1998). Two subspecies, the Point Arena Mountain Beaver, *A. rufa nigra*, and the Point Reyes Mountain Beaver, *A. rufa phaea*, are listed as "Vulnerable" due to their very small and isolated populations. The IUCN defines their term "Vulnerable" as facing a "high risk of extinction in the wild in the medium-term future" but as not being Critically Endangered or Endangered. This IUCN definition of "Vulnerable" would more closely approximate the COSEWIC ranking of Threatened (a species likely to become endangered if limiting factors are not reversed) than the COSEWIC ranking of Vulnerable.

Orchard (1984*) assigned the Mountain Beaver to the "Not at Risk" category, despite possible threats to the species in Canada, because there were extremely few data available upon which to make any designation. There is now a much better idea of the distribution of the Mountain Beaver in Canada, and more is known about possible threats to the species. The Mountain Beaver has now been designated as vulnerable in Canada by COSEWIC (Gyug 1999*). This is because of the virtual elimination of the species from the flatlands of the lower Fraser Valley, the reduction and isolation of populations in the Fraser Valley foothills by suburban development, and because of the high susceptibility of Mountain Beaver habitat to destruction by high intensity forest management practices.

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APPENDIX 1. British Columbia Mountain Beaver specimens in North American museums as compiled by David Nagorsen of the Royal British Columbia Museum. Records are mapped on Figure 1A as numbered here. Precision of locations is within three minutes of latitude and longitude, or better, for each location. Specimens of unsure precision (except limited locations) were not assigned latitude and longitude, and were not mapped. Consecutive series of specimen numbers are abbreviated (e.g., 5189-91 for three consecutive specimen numbers).

Loc. No.	Museum ¹	Catalogue Numbers	Number of Specimens	Year Collected	Location	Subspecies	Latitude (deg min N)	Longitude (deg min W)
1	CMN	28784	1	1947	13 mi. NE of Canford	<i>rainieri</i>	50 17?	120 48?
2	CMN	8903-4	2	1928	Stirling Creek [= Whistle Creek]	<i>rainieri</i>	49 21	120 05
3	UBC	8021	1	1956	Treasure Mountain, S slopes	<i>rainieri</i>	49 25	121 04
4	RBCM	17038	1	1987	Vuich Creek	<i>rainieri</i>	49 24	121 03
5	CMN	7884, 7900	2	1927	Hope-Princeton Summit	<i>rainieri</i>	49 17	120 49
6	MVZ	116255, 116256	2	1952	Manning Park HQ, 3 miles E	<i>rainieri</i>	49 04	120 43
7	UBC	4294-5	2	1952	Manning Park, Windy Joe Mt. Road	<i>rainieri</i>	49 04	120 46
8	UBC	2942-4	3	1949	Manning Park, Ranger Station	<i>rainieri</i>	49 04	120 47
9	UBC	2945	1	1949	Manning Park, 2 miles W Ranger Station	<i>rainieri</i>	49 05	120 49
10	RBCM	5189-91	3	1945	Manning Park, 1 mile W of Allison Pass	<i>rainieri</i>	49 09	120 53
-	UBC	3021-2	2	1949	Manning Park [unspecific location]	<i>rainieri</i>		
11	RBCM	5188	1	1945	Timberline Valley	<i>rainieri</i>	49 12	120 57
12	CMN	1172-4, 1180-1	5	1905	Skaist River	<i>rainieri</i>	49 13	120 57
13	RBCM	5489	1	1949	Mount Gordon	<i>rainieri</i>	49 07	121 01
14	UBC	2378-9	2	1947	Steamboat Mt. [=Shawatum Mt.]	<i>rainieri</i>	49 06	121 03
15	MVZ ¹	116303	1	1949	Ten-Mile Creek, 10 miles SE of Hope ²	<i>rufa</i>	49 20	121 18
-	MVZ	116304-12	9	1949	Ten-Mile Creek, 25 miles SE of Hope ²	<i>rainieri</i>		
-	USNM	Specimen missing	0	1906	Skagit River	<i>rainieri</i>		
16	MCZ	1892B-95B	4	1894	Lake House [=Hope Slide area, 16 km SE of Hope]	<i>rainieri</i>	49 18	121 16
-	MCZ	1896B-1900B	5	1894	Hope, Roab's Ranch	<i>rufa</i>		
17	CMN	7454-5, 7471	3	1927	Hope	<i>rainieri</i>	49 23	121 26
17	UBC	5905	1	1930	Little Mountain [=Thacker Mt.], Hope	<i>rufa</i>	49 23	121 25
18	MCZ	6822B	1	1895,	Chilliwack	<i>rufa</i>	49 11	121 55
18	RBCM	274	1	1895	Chilliwack, near mouth of Fraser River	<i>rufa</i>	49 11	121 55
18	USNM	94348	1	1895	Chilliwack	<i>rufa</i>	49 11	121 55
18	MCZ	6824-5B	2	1896	Chilliwack	<i>rufa</i>	49 11	121 55
18	USNM	Specimen missing	0	1902	Chilliwack	<i>rufa</i>	49 11	121 55
18	RBCM	3499	1	1938	Chilliwack	<i>rufa</i>	49 11	121 55
19	RBCM	2524	1	1938	Vedder Crossing	<i>rufa</i>	49 07	121 58
-	CMN	710, 713, 715, 726-7, 813, 815, 856-8, 860-5, 871-2, 876-80, 884-6	28	1901	Chilliwack Valley [unspecific locations probably E of location 19 in Chilliwack River valley]	<i>rufa</i>		
20	CMN	7835-6, 7850	3	1927	Lihumpton Park	<i>rufa</i>	49 02	121 52
21	USNM	88009	1	1895	Cultus Lake	<i>rufa</i>	49 04	121 58

continued

Loc. No.	Museum ¹	Catalogue Numbers	Number of Specimens	Year Collected	Location	Subspecies	Latitude (deg min N)	Longitude (deg min W)
21	CMN	7375	1	1927	Cultus Lake	<i>rufa</i>	49 04	121 58
21	UBC	2444	1	1947	Cultus Lake	<i>rufa</i>	49 04	121 58
22	UBC	5903	1	1919	Vedder Mountain, Yarrow	<i>rufa</i>	49 03	122 03
22	UBC	5904	1	1921	Vedder Mountain, Yarrow	<i>rufa</i>	49 03	122 03
22	UCLA	16396, 17855	2	1921	Vedder Mountain	<i>rufa</i>	49 03	122 03
22	ROM	2704140004	1	1924	Vedder Mountain	<i>rufa</i>	49 03	122 03
-	MCZ	6823B	1	1896	Mount Baker Range	<i>rufa</i>		
23	ROM	2704140014	1	1930	Vedder Mountain, Sumas Prairie	<i>rufa</i>	49 05	122 07
24	RBCM	10496	1	1974	Sumas Mountain	<i>rufa</i>	49 06	122 11
25	RBCM	101	1	1974	Abbotsford	<i>rufa</i>	49 04	122 17
-	USNM	88008	1	1895	Sumas [= Huntingdon? ²]	<i>rufa</i>		
26	CMN	7255, 7546, 7617, 7683, 7691	5	1927	Huntingdon	<i>rufa</i>	49 00	122 16
26	ROM	17184	1	1927	Huntingdon	<i>rufa</i>	49 00	122 16
26	CMN	7720, 11162-3	3	1929	Huntingdon	<i>rufa</i>	49 00	122 16
26	UBC	343-6	4	1929	Huntingdon	<i>rufa</i>	49 00	122 16
26	ROM	24713, 30299	2	1930	Huntingdon	<i>rufa</i>	49 00	122 16
26	UBC	342, 5901-2	3	1930	Huntingdon	<i>rufa</i>	49 00	122 16
26	UBC	5899-900	2	1934	Huntingdon	<i>rufa</i>	49 00	122 16
26	RBCM	1550	1	1935	Huntingdon	<i>rufa</i>	49 00	122 16
26	UBC	3648	1	1938	Huntingdon	<i>rufa</i>	49 00	122 16
26	CMN	16139	1	1939	Huntingdon	<i>rufa</i>	49 00	122 16
26	UBC	439, 771-3	4	1941	Huntingdon	<i>rufa</i>	49 00	122 16
26	UBC	685	1	1942	Huntingdon	<i>rufa</i>	49 00	122 16
26	CMN	28785	1	1948	Huntingdon	<i>rufa</i>	49 00	122 16
26	UBC	5897-8	2	1950	Huntingdon	<i>rufa</i>	49 00	122 16
26	MMN	100	1	1952	Huntingdon	<i>rufa</i>	49 00	122 16
27	RBCM	7425	1	1969	Langley [exact location unspecified, see text]	<i>rufa</i>	49 06?	122 41?

¹UBC=University of British Columbia; RBCM=Royal British Columbia Museum (formerly British Columbia Provincial Museum); CMN=Canadian Museum of Nature (formerly National Museums of Canada); USNM=United States National Museum; MCZ= Museum of Comparative Zoology, Harvard; ROM=Royal Ontario Museum; MVZ=Museum of Vertebrate Zoology; UCLA=University of California at Los Angeles; MMN=Manitoba Museum of Man and Nature.

²Ten-Mile Creek is NE of Hope, not SE. There are currently only Eight-Mile and Eleven-Mile Creeks SE of Hope. Reference may be to Wray Creek which meets the Hope-Princeton Highway (newly opened in 1949) 10 miles SE of Hope. I am not sure if the 9 specimens collected at "Ten-Mile Creek, 25 miles SE of Hope" were actually obtained from the same location as the previous record or perhaps at Twenty-Six Mile Creek SE of Hope.

³The town of Sumas is south of the Canada-U.S. Border with the name Huntingdon applied to the area on the Canadian side. Reference may be to Huntingdon, or to the general area of Sumas Prairie along the Sumas River.

APPENDIX 2. Location of British Columbia observations of Mountain Beavers or Mountain Beaver sign west of the Cascade Mountain divide and in Manning Provincial Park. Records are mapped on Figure 1B as numbered here. Precision of locations is to the minute of latitude and longitude.

No.	Location	Latitude (deg min N)	Longitude (deg min W)	Year	Observer or Source
28	Siska Creek	50 07	121 29	1997	Donna Romain
29	Anderson River	49 50	121 18	1998	Les Gyug
30	Uztlius Creek	49 53	121 23	1998	Les Gyug
31	Boston Bar Creek	49 35	121 10	1999	Les Gyug
32	Dewdney Creek	49 24	121 08	1999	Les Gyug
33	Sowaqua Creek	49 17	121 02	1999	Les Gyug
34	Sumallo River	49 13	121 15	1970s	Kay Keding
35	East of Hampton Creek	49 04	120 43	1945–1950	Carl et al. (1952)
36	Castle Creek	49 01	120 48	1979	Cosco (1980)
37	Frosty Mountain	49 02	120 51	1945–1950	Carl et al. (1952)
38	Allison Pass	49 07	120 52	1945–1950	Carl et al. (1952)
39	Foley Creek	49 07	121 38	1997	Martin Gebauer
40	Foley Creek	49 07	121 35	1997	Martin Gebauer
41	Chipmunk Creek	49 07	121 39	1997	Martin Gebauer
42	Chipmunk Creek	49 07	121 40	1997	Martin Gebauer
43	Tamihi Creek	49 03	121 50	1997	Martin Gebauer
44	Chilliwack River	49 04	121 43	1979	Cosco (1980)
45	Chilliwack River	49 04	121 48	1979	Cosco (1980)
46	Ryder Lake	49 06	121 53	1997	Dennis Knopf
47	Mt. Tom	49 06	121 55	1997	Dennis Knopf
48	Mt. Shannon	49 11	121 55	1970s	Dennis Knopf
49	Top of Sumas Mountain	49 07	122 09	1979	Cosco (1980)
49	Top of Sumas Mountain	49 07	122 09	1990s	Johanna Saaltink
50	West end of Sumas Mountain	49 05	122 14	1979	Cosco (1980)

Notes

Blastomycosis in a Free Ranging Lone Wolf, *Canis lupus*, on the North Shore of Lake Superior, Ontario

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Krizan, Peter. 2000. Blastomycosis in a free ranging lone Wolf, *Canis lupus*, on the north shore of Lake Superior, Ontario. *Canadian Field-Naturalist* 114(3): 491–493.

An adult male Wolf was trapped and radio-collared in 1994 on the north shore of Lake Superior, Ontario. He left his former pack in the same year and was nomadic until his death in 1996. The cause of death was determined to be blastomycosis, a fungal infection uncommon in the area.

Key Words: Wolf, *Canis lupus*, blastomycosis, fungus, Lake Superior, Ontario.

There are two recorded cases of fatal fungal infections in Wolves in North America (Thiel et al. 1987). Both Wolves were found infected with *Blastomyces*, a dimorphic fungus *Blastomyces dermatitidis* that can cause systemic disease in canids (Thiel et al. 1987), cats (Meschter and Heiber 1989), and humans (Archer et al. 1987). In Ontario, the few cases reported occurred in northwestern Ontario in domestic animals and Red Foxes, *Vulpes vulpes* (S. Anderson, Ontario Ministry of Natural Resources, Kenora district, personal communication), and one case of blastomycosis was reported from the immediate study area in a dog (W. Potter, Highview Animal Clinic, Thunder Bay, Ontario, personal communication). I report on the occurrence of blastomycosis in one male Wolf from the north shore of Lake Superior, Ontario.

Study Area

This study was done from October 1994 to February 1996 on the north coast of Lake Superior in Ontario, between Sault Saint Marie and Thunder Bay. The incident occurred north of Pukaskwa National Park in the White River Forest. The habitat has been logged extensively and is accessible by numerous logging roads; clear cuts, lakes, and rivers depict a patchy landscape.

Methods

I captured Wolves with number 14 Newhouse steel traps (Krizan 1997). Each Wolf was weighed, ear-

tagged, and radio-collared. Radio-collared Wolves were located from a Cessna 185 fixed wing aircraft once per week (White and Garrot 1990; Krizan 1997). I plotted all telemetry locations on Department of Energy, Mines, and Resources 1:50 000 topographic maps in UTM format. A home range was defined by 95% of all the telemetry locations using the adaptive kernel method (Worton 1989; Shivik et al. 1996) calculated by the program CALHOME®.

To test differences in the distances traveled between successive locations Man-Whitney U-test was used after testing for normality with Wilk-Shapiro test. Proximity to water was defined as any location occurring within 100 m of a river, creek, lake, or swamp. Telemetry location data were divided into summer and winter. Winter locations were defined as those collected during 16 January - 29 March (winter 1994-1995) and 01 January - 20 February (winter 1995-1996). The remainder of the time, waterways were assumed to be open and not suitable for travel (summer locations). Locations within 100 m of the landfill site were recorded as dump locations.

Results

A young adult male Wolf from the Rein Lake Pack was radio-collared on 3 October 1994, near Pukaskwa National Park. He was associated with at least two other Wolves at the time, weighed 32 kg and was in good condition. He was located by radio telemetry 7 times with his original pack, and 66 times alone after his dispersal in September 1994. From October 1994 to February 1996, the size of his home range was 2782 km², larger than the home

*See Documents Cited section.

range of his former pack during the same time (i.e., 834 km²). Of 27 visual locations after dispersal, he was observed with one other Wolf on five occasions, three Wolves on three occasions, and alone on 19. Six weeks before he died, the Wolf was located consistently at a garbage dump. From the time the Wolf arrived at the dump in January 1996, his mean travel distance between weekly locations decreased significantly ($P < 0.001$) from 13 300 m (SE = 1839) previously to 1624 m (SE = 1023). Before his arrival to the garbage dump, the Wolf was observed near Beaver (*Castor canadensis*) dams and feeding one time on a Beaver. In 43% of all telemetry locations he was located on or in close proximity to waterways. There was no significant difference ($P = 0.68$) between the summer and winter use of waterways. Forty four percent of all locations at waterways occurred in the summer compared to 56% in the winter. He was found dead on 22 February 1996.

The Wolf was found lying on his left side on a ridge about 30 km north east of Pukaskwa National Park. There were no signs of struggle. Examination of the carcass revealed a wound and fracture of the left forelimb, the hindquarters showed two subcutaneous lacerations, and the bone marrow was gelatinous. Necropsy of the Wolf showed that blastomycosis was the actual cause of death (D. Campbell, Canadian Cooperative Wildlife Health Centre, University of Guelph, personal communication). The necropsy results were similar to that of Thiel et al. (1987). Necropsy of eight other Wolves from the study area showed no other incidents of blastomycosis.

Discussion

The only two Wolves reported to have blastomycosis in the Lake Superior region occurred in Minnesota and Wisconsin (Thiel et al. 1987). The case reported here represents an extension of this disease to northern Ontario where its exact distribution is unclear.

The free-living mycelial stages of the fungus reside in soil or decaying organic matter and produce spores that are potentially infectious to vertebrates (Wolf 1989). In Wisconsin, blastomycosis has been associated with waterways (Klein et al. 1987; Wolf 1989; Baumgardner et al. 1992; Baumgardner et al. 1995). Sites were characterized as damp; moist, and humid with water tables near the soil surface and abundant organic matter from wildlife droppings (Archer et al. 1987; Klein et al. 1987). Beaver dams were noted to have the characteristics of infection sites (Klein et al. 1986).

The source of infection in the reported Wolf is unknown. The Wolf traveled in a very large area and was located at or close to Beaver dams, waterways and swamps year-round. Because the Wolf traveled predominantly alone, it is probable that consumption of smaller prey such as Beaver and scavenged prey from other kills that he may have

dug up at caches of other packs may have exposed him to the fungus. According to Baumgardner (1991), a higher risk of infection has been associated with excavating activities in areas endemic to blastomycosis. An increased association to waterways and Beaver habitat may have increased his likelihood of encountering the fungus.

The necropsy results were similar to those reported by Thiel et al. (1987) in that the fungus had spread throughout many organs, including the bones, and may have predisposed him to the possibility of a fracture. Decreased travel distances during the last six weeks of his life suggest that he was unable to travel and hunt and the observed gelatinous bone marrow suggest poor physical condition (LaJeunesse and Peterson 1993).

Krizan (1997) suggested that Wolves on the north shore of Lake Superior may have been malnourished due to low Moose (*Alces alces*) densities, and therefore may have been more susceptible to diseases. Two of three Wolves of the remaining members of his original pack died of sarcoptic mange (*Sarcoptes scabiei*) by February 1997 (Krizan 1997); this evidence lends support to this idea.

Acknowledgments

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Body Sizes, Ages, Reproductive Status, and Sex Ratios of Arctic Foxes, *Alopex lagopus*, in the Prudhoe Bay Oil Field, Alaska

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Ballard, Warren B., Matthew A. Cronin, Martin D. Robards, and Erich H. Follmann. 2000. Body sizes, ages, reproductive status, and sex ratios of Arctic Foxes, *Alopex lagopus*, in the Prudhoe Bay Oil Field, Alaska. Canadian Field-Naturalist 114(3): 493–494.

Due to public safety concerns about exposure to rabies by Arctic Foxes (*Alopex lagopus*) in the Prudhoe Bay oil field, Alaska the fox population was reduced in 1994. Ninety-nine foxes were killed during January–February 1994; 59% were males and 41% were females. Eighty-nine percent of the foxes were juveniles. The large proportion of juveniles may reflect a skewed age structure with relatively few adults, but it could also represent a capture bias towards juveniles. Male foxes were longer and heavier than female foxes.

Key Words: Arctic Fox, *Alopex lagopus*, body size, reproductive status, sex ratios, Alaska.

The likelihood of more dense and stable Arctic Fox (*Alopex lagopus*) populations at Prudhoe Bay, Alaska (Eberhardt et al. 1982, 1983a,b; Rodrigues et al. 1994*) led to concerns about the potential effects on humans and wildlife, particularly the threat of rabies transmission. After attacks on oil field personnel in 1993, the fox population in the Prudhoe Bay oil field area, Alaska was reduced in 1994. Specimens taken in this program allowed quantification of body condition, reproductive status, age, and sex ratios for this Arctic Fox population. Foxes were also tested for rabies, distemper, and heavy metal contamination but these are reported elsewhere (Robards et al. 1996*).

Study Area

The study was conducted in the Prudhoe Bay oil field and included the Prudhoe Bay Unit (within

147°50'–149°10' N longitude and 70°25'–70°10' W latitude). The area has been described by Pollard et al. (1996) and Cronin et al. (1998).

Methods

During 11 January through 4 February 1994 Arctic Foxes were live trapped with Havahart traps and then shot. Sex, hind foot length, and body length (tip of nose to tip of tail) were recorded for 99 foxes, while the weights of 19 foxes taken in February were also recorded. Reproductive tracts were removed from females and testicles from males of all foxes trapped during January ($n = 80$). Female tracts were examined for placental scars as indicators of reproductive activity. Testicles from 49 foxes were paraffin embedded, thin-sectioned, and examined for developing spermatozoa.

Ages of 80 foxes were determined by aging canine teeth by methods in Grue and Jensen (1976) and

*See Documents Cited section.

Bradley et al. (1981), and were aged by Matson's Laboratory (Milltown, Montana). Some foxes ($n = 19$) were aged as juveniles based upon body size and in these cases no canines were aged.

Significant differences in means were determined by two-tailed Student's t -test with $P \leq 0.05$ required for significance. Mean values are presented \pm standard deviation (SD).

Results and Discussion

Eighty-seven (89%) of the 99 animals aged by tooth cementum analysis or body size were juvenile foxes born the previous May or June 1994, seven (7%) were aged 1-year, three (3%) were aged 2-year, and one (1%) was aged 5-years. Our results were consistent with those of Prestrud et al. (1994) for Svalbard, Norway, and those of Hiruki and Stirling (1989) on Banks Island, Northwest Territories, Canada, where juvenile Arctic Foxes were the most abundant age class. Hiruki and Stirling (1989) indicated that juvenile survival rates were low (i.e., $<8\%$) resulting in low numbers in subsequent year-classes. However, juvenile Arctic Foxes are less experienced in foraging, more naïve than adults, and more capture-prone than adults and thus they may be over-represented relative to adults. Fifty-eight of 99 foxes were male and 41 were female. Of the juvenile foxes, 48 were males and 39 were females.

Male Arctic Foxes were heavier and longer than females (weights = 4.3 ± 0.6 kg vs 3.6 ± 0.6 kg, $n = 19$; lengths = 571.6 ± 38 mm vs 540.6 ± 29 mm, $n = 99$; both $P \leq 0.05$). Hind foot lengths of females were shorter ($P \leq 0.05$) than those of males. Mean total body weight of Arctic Foxes collected at Svalbard, Norway, was 3.6 ± 0.9 kg ($n = 45$) for males and 3.2 ± 0.6 kg for females (Prestrud et al. 1984). Svalbard Arctic Foxes appear smaller than Prudhoe Bay foxes. Svalbard males were larger than females but the difference was not significant (Prestrud et al. 1984).

Only two mature females were included in the sample and one 1-year old had 9 placental scars and a 2-year old had 13 placental scars. Scars of the latter fox had varied pigmentation suggesting that the scars represented two litters in presumably different years. All other female foxes ($n = 49$) were immature juveniles that had not reproduced.

Of 49 males analyzed for spermatozoa, none were fertile, not unexpected as no breeding or courtship takes place during January and February and juveniles would not be producing sperm.

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Behaviour and Body Weight fluctuations of the Eurasian Red Squirrel (*Sciurus vulgaris*) in the Mating Season

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Lee, Tsung Hung. 2000. Behaviour and body weight fluctuations of the Eurasian Red Squirrel, *Sciurus vulgaris*, during pregnancy and lactation. Canadian Field-Naturalist 114(3): 495–497.

One female squirrel was studied in Nopporo Forest Park (43°20'N, 141°30'E), in west Hokkaido, Japan. During the pregnancy, she moved from a main nest to the breeding nest and then built a few new nests (5 spherical dreys). In lactation stage, she departed from her den later in the morning than during the pregnancy period. When other male squirrels were in proximity, she attacked them. She carried her litters and moved to other dreys about 30-days after parturition. Her body weight was weighed ranged from 371 g to 397 g at the pregestation stage, increased steadily during the pregnancy period, and attained the maximum, 504 g, just before parturition. After parturition, her body weight decreased abruptly about 12% (from 504 g down to 443 g). Her daily change rate of body weight (DCBW) was 2.91 % in the pregestation period, 3.03 % in the pregnancy period, and 6.93 % in the lactation period.

Key Words: Eurasian Red Squirrel, *Sciurus vulgaris*, weight fluctuation, pregnancy, lactation, Japan.

Body weights of tree squirrels fluctuate seasonally according to the changes in food consumption and reproductive states (Short and Duke 1971; Knee 1983). Weights are also correlated with litter size and survival in some non-hibernating rodents (Myers and Master 1983; Sauer and Slade 1986). In the Eurasian Red Squirrel, *Sciurus vulgaris* L., the body weight can be positively related to dominance order and reproductive success (Wauters and Dhondt 1989). Thus, the larger (heavier) the female, the more safely she overwinters and the earlier she comes into estrus, enabling her to have two litters within a season. She can also nurse her litter(s) successfully depending on abundant high energy food that she hoarded in her home range (Wauters et al. 1995). Wauters and Dhondt (1989) suggested that females of the Red Squirrel weighing < 300 g do not come into estrus, and that body weight is the best predictor of fertility. The body weight, therefore, is a useful measurement and indicator for size, physical condition, and reproductive state of the Red Squirrel.

In this study, one female squirrel was auto-weighed in the breeding season to show the body weight changes in detail, and her breeding behaviour was described.

Materials and Methods

Research was conducted in Nopporo Forest Park (NFP), with an area of 2051 ha (43°20'N, 141°30'E), which is situated in west Hokkaido, 11–15 km east of Sapporo, Japan. This forest has become completely isolated from other areas of lowland forest as a result of the spread of both by agriculture and urbanization. It consists mainly of natural forests and partly of plantations of coniferous trees, and is designated as a natural monument and recreational forest, and a wildlife protection area (Tatewaki and Igarashi

1973). One female red squirrel, which was observed starting on 20 June 1996 and which became habituated to the author was selected as the target animal. She was trapped by the live-trap (60 × 15 × 15 cm) baited with a mixture of sunflower seeds, Walnuts (*Juglans ailanthifolia*) and seeds of Korean Nut Pine (*Pinus koraiensis*), and then was equipped with color-coded radio-telemetry collars (5.5 g in weight, Maeda Technical Laboratory, Japan).

From 10 February to 28 May, her behaviour (including nest use and building, interaction with other squirrels, and feeding) was traced by visual observation and/or radio telemetry through each day. To monitor her body weight changes in detail in different stages of the breeding season, pregestation, pregnancy, and lactation were divided by calculating back from the known parturition date, assuming a 39-day gestation period (Yamatani 1969; Takaragawa 1996). To measure her body weight easily and frequently, I placed the auto scale on the runways. When she got closer to the scale, about ten sunflower seeds were put on it to invite her, then if the squirrel climbed onto the scale I recorded its body weight directly (Figure 1). Her body weight was measured in field two to five times a day (each measurement separated by at least 2-hour intervals) from 27 February to 28 May 1997, for a total of 142 times for 42 days. I calculated the daily change rate of body weight (DCBW) by the following formula: $DCBW (\%) = 100 (\text{maximum body weight} - \text{minimum body weight}) / (\text{average body weight})$.

Results

Behaviour was characterized as follows: In the early pregnancy, she moved from a main nest (spherical drey) to the breeding nest (den). In the mid-pregnancy, she built a few new nests (5 spheri-



FIGURE 1. Measurement of the body weight by an auto scale.

cal dreys). In the late pregnancy, she took longer rests in trees. I identified parturition by a sudden drop in her body mass, the presence of elongated nipples and matted fur, later departure from her den, faster movement and eating, and more food consumed than during the pregnancy period. Later morning departure from the den than during the pregnancy was characteristic of the lactation period. When other male squirrels were in proximity, she attacked them. She carried her litter and moved to other dreys about 30-days after parturition.

Her body weight ranged from 371 g to 397 g during the pregestation stage, increased steadily during the pregnancy period, and attained the maximum, 504 g, just before parturition (Figure 2). After parturition, her body weight decreased abruptly about 12% (from 504 g down to 443 g) and then linearly down to 392 g at the fifth day after parturition. Thereafter, her weight recovered slightly and fluctuated in the range of 415 g to 480 g. Moreover, her daily rate of change rate of DCBW was 2.91% in pregestation period, 3.03% in the pregnancy period, and 6.93% in the lactation period. Clearly, the daily body weight fluctuations were greater during lactation than pregnancy, and both were greater than the pregestation period.

Discussion

Although body weights of squirrels can be taken in the field when trapping by using a Pesola spring-balance (Wauters and Dhondt 1989, Wauters et al. 1993), squirrels may not be trapped and weighed frequently during pregnancy as this can produce undue stress and even lead to death of the squirrel. A scale placed on the runways could monitor the body weight of one red squirrel accurately and frequently in the field during pregnancy and lactation periods without the stress of handling.

The body weight of several tree squirrels varies both between individuals and seasonally (Short and Duke 1971; Wauters and Dhondt 1989). The means of the female, but not male, body weights are at the maximum value subsequent to the mating (Short and Duke 1971) due to the effects of pregnancy and lactation for one or two litters.

Body weights of respiratory disease-free cats (*Felis catus*), change with an increase per week steadily in the gestation period, but decrease during lactation (Loveridge 1986). However, the Red Squirrel studied here showed the same phenomenon during gestation, but not during the lactation. The increase of the body weight was mainly due to the development of the embryos. However, after parturition, i.e., during lactation, the body weight was still at the higher level with fluctuations of up to 10% within one day. Red Squirrel juveniles are weaned when 10 weeks old (Gurnell 1987). Litter size, juvenile body weight and survival are positively affected by the mothers' body weight during lactation (Wauters and Dhondt 1989; Wauters et al. 1993). Juvenile diet depends nearly exclusively on the mother's milk before weaning. Thus, the mother must eat, digest, absorb, and use large amounts of nutrients to produce sufficient milk of adequate composition to support the growth and development of their pups. Therefore, energy requirements of lactating squirrels are much higher than in those not lactating (Havera 1979; Smith 1968). The energy requirement or energy level of the lactating period also is much higher than that during pregnancy in captive mammals such as Bank Vole (*Clethrionomys glareolus*), cat, and rat (*Rattus norvegicus*) (Kaczmarek 1966; Loveridge 1986; Prado et al. 1997). Finally, that owing to nursing her litters successfully, the mother squirrel has a higher food intake which results in an increase of her body weight; while subsequent feeding of her litters results in a decrease. In lactation period, a rich-energy food intake is particularly important to maintain a female's weight.

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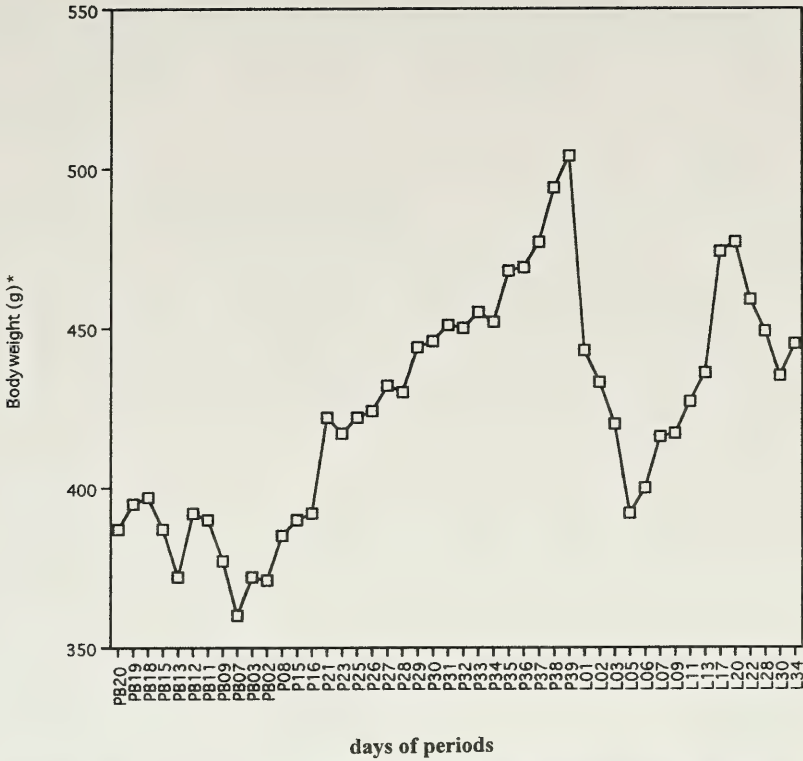


FIGURE 2. Body weight changes in one squirrel in pregnancy and lactation: PB *n*: the *n* days before pregnancy; P *n*: the *n* days of pregnancy; L *n*: the *n* days of lactation; *: female mean body weight on that day.

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A Denning Brown Bear, *Ursus arctos*, Sow and Two Cubs Killed in an Avalanche on the Kenai Peninsula, Alaska

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Hilderbrand, Grant V., Larry L. Lewis, Jonathan Larrivee, and Sean D. Farley. 2000. A denning Brown Bear, *Ursus arctos*, sow and two cubs killed in an avalanche on the Kenai Peninsula, Alaska. *Canadian Field-Naturalist* 114(3): 498.

A denning adult female Brown Bear and her two cubs were killed by an avalanche during the winter of 1997–1998 on the Kenai Peninsula, Alaska. Denning bears may be vulnerable to human-caused avalanches resulting from popular winter recreation activities such as skiing, snowboarding, and snowmobile travel on steep slopes. The current popularity of helicopter assisted skiing and snowboarding means that even bears denning in remote sites may be at risk and small bear populations could be adversely affected.

Key Words: Alaska, avalanche, brown bear, mortality, *Ursus arctos*

We document the avalanche-caused mortality of a denning brown bear (*Ursus arctos*) sow and her two cubs. Avalanche-caused mortality has been documented in Caucasian goats, Chamois, deer, Tur, wolves, Ibex, and brown bear (Formozov 1946, Boyd et al. 1992, Kudaktin and Clustin 1993, Haller 1996).

In the fall of 1997, a radio-collared 9-year-old female Brown Bear and her two cubs (age 9 months) entered a den ~3775 m east of Skilak Glacier Lake in the Chugach Mountains (elevation ~930 m) on the Kenai Peninsula, Alaska. Multiple telemetry locations collected the following spring centered very close to the den site. After snow melt, the site was visited by helicopter in July and the carcass of the sow was found in an avalanche chute mixed with rocks and debris. Much of the carcass had been scavenged by the time of our visit. We followed a trail of hair and den bedding materials ~50 m up slope (~11°) and found the remains of her two cubs. The cubs were buried in ~1.5 m of snow and scavengers had tunneled down to the carcasses. The den, which was identified previously during radio-tracking flights, was no longer present as the surrounding rock and earth had been collapsed.

Avalanches can contribute to natural mortalities in wild Brown Bear populations. Human activities including snowmobile use on steep slopes and skiing and snowboarding in remote areas accessed by helicopter may cause avalanches that could kill denning bears. Thus, when Brown Bear conservation is a management objective (e. g., small and/or isolated

populations), control of human access and activities may be an important management issue because the loss of a few individual bears may have strong negative effects on population viability.

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Notes on the Pollination and Dispersal of Goldenseal, *Hydrastis canadensis* L., in Southwestern Ontario

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Sinclair, Adrienne, Paul M. Catling, and Louise Dumouchel. 2000. Notes on pollination and dispersal of Goldenseal, *Hydrastis canadensis* L., in southwestern Ontario. *Canadian Field-Naturalist* 114(3): 499–501.

Based on pollination experiments with seven plants, pollination is required for seed set in Goldenseal and there is at least a degree of self-compatibility. Of 26 floral visitors, the primary pollinators were small polylectic bees, 6–7 mm long, referable to the genera *Dialictus* and *Evylaeus*. Syrphid flies as well as some larger bees, 8–10 mm long, including an *Andrena* sp., a *Bombus* sp., and *Augochlora pura pura* (Say), also serve as pollinators. Fruit was removed quickly and evidence suggests that Red-winged Blackbirds (*Agelaius phoeniceus* (L.)) can serve as effective dispersal agents. Although limited, these observations suggest that neither pollination nor dispersal are restrictive to population growth.

Key Words: Goldenseal, *Hydrastis canadensis*, pollination, bees, flies, dispersal, threatened, Ontario, protection.

A rough-hairy perennial woodland herb, Goldenseal (*Hydrastis canadensis* L.) is considered threatened in Canada (White 1991*; Sinclair and Catling 1998a*, 1998b*, 2000). It has been noted that the conspicuous mass of stamens suggests pollination by pollen-gathering bees and that the colour, top position, and rapid disappearance of the fruit suggest dispersal by birds (Sinclair and Catling 2000; Welty 1962). Currently, no more definite information is available on the pollination and dispersal of Goldenseal. The need for information on insect pollination, for protection, was recently highlighted by the USFWS (1997*). Here we report on observations made during 1999 that provide the first evidence of pollination and dispersal mechanisms and their relevance with respect to population growth.

Methods

Prior to blooming, seven plants with flower buds were collected at random, from sites near Bothwell (42° 38' N, 81° 52' W) and Durham (45° 10' N, 80° 49' W), and manipulated as described below to evaluate evidence for the relative importance of self-pollination.

Four plants were isolated in a glasshouse and their anthers were removed. Three plants were placed separately outside in a natural setting where no Goldenseal occurs so that only self-pollination via agitation or insects was possible. Within flowers of four plants, pollen was transferred intraflorally, using a paint brush. These flowers were isolated from pollinators using nylon netting and tubes.

Observations of pollination were made at four sites in the Lake Erie Lowland Ecoregion 135 of the Mixedwood Plains Ecozone in Ontario (Ecological Stratification Working Group 1995*) during the first week of May 1999. Sites are named according to the

nearest town or village (latitude and longitude given): Amherstburg (42° 06' N, 83° 06' W in Malden Township of Essex County), Arner (42° 02' N, 82° 49' W in Gosfield South Township of Essex County), Watford (42° 57' N, 81° 53' W in Warwick Township of Lambton County), and Uttoxeter (43° 02' N, 82° 03' W in Plympton Township of Lambton County). Observations of dispersal were made at the Arner site on 13 July.

Insect activity was noted in the field during morning and afternoon periods on 5 and 6 May. All visitors and pollinators seen were recorded. An insect that visited only one flower was defined as a visitor, whereas, an insect that visited two or more flowers consecutively (permitting pollen transfer) was defined as a pollinator.

Results and Discussion

None of the four isolated emasculates produced fruit suggesting the requirement of pollination for fruit production. All three plants isolated separately in a natural setting produced fruit, either through insect activity and/or as a result of wind and/or rain, suggesting that plants are self-compatible and pollination can occur in isolated plants. This limited evidence suggests that pollination is required for seed set.

The primary pollinators were small bees, 6–7 mm, referable to the genera *Dialictus* and *Evylaeus* (Table 1). Syrphid flies as well as some larger bees, 8–10 mm long, including an *Andrena* sp., a *Bombus* sp., and *Augochlora pura pura* (Say), also appear to act as pollinators. The small bees are mostly polylectic and thus pollinator specificity seems unlikely. Other studies of vernal woodland herbs have suggested the importance of small bees (Bertin and Sholes 1993) and have also emphasized the impor-

TABLE 1. Insect visitors (i.e., visiting only one flower) and pollinators (i.e., visiting two or more flowers consecutively) of *Hydrastis canadensis* at four sites in Essex County, showing numbers of individuals observed at each site from 5 to 6 May, 1999.

Taxa of Visitors/Pollinators ¹	Amherstburg vis./poll.	Arner vis./poll.	Watford vis./poll.	Utttoxeter vis./poll.	Total vis./poll.
Flies					
1. <i>Eupiodes</i> sp.		0/1			0/1
2. cf. <i>Eupiodes</i> sp.		1/2	0/1	2/0	3/3
Bees²					
3. <i>Andrena</i> sp., 10 mm long		0/1			0/1
4. <i>Augochlora pura pura</i> (Say), 8 mm long	0/1				0/1
5. cf. <i>Augochlora pura pura</i> (Say)	2/2	0/2			2/4
6. <i>Bombus</i> sp.	0/1				0/1
7. <i>Dialictus</i> sp., 6-7 mm long, hairy abdomen, green metallic thorax		0/6	0/2		0/8
8. <i>Evyaleus</i> sp., 6 mm long with pure black thorax		0/2	0/1		0/3
9. small bees, 6-7 mm long, probably <i>Dialictus</i> and <i>Evyaleus</i> sp.	3/3	4/9	1/2	2/2	10/16

¹Up to three specimens of each group listed were collected and deposited in the Canadian National Collection (Entomology) maintained by Agriculture Canada in Ottawa (except for 2, 5, 6, 9).

²Identifications by Louise Dumouchel. Because of the largely polylectic nature of these groups identification to species level is impractical at present.

tance of a diversity of pollinators (Beattie 1971; Motten 1986).

Since the bees spent up to a minute crawling over an individual flower, the flowers appear to be attractive. The crawling may have involved acquisition of pollen on the surface of the insects, as evidenced by some bees which were covered with *Hydrastis* pollen, that could later be gleaned. This crawling behaviour may represent an adaptation to the prominent stamen cluster morphology of the flower, a morphology shared by other woodland herbs such as Dwarf Ginseng (*Panax trifolius* L.) and False Mitrewort (*Tiarella cordifolia* L.) which were flowering at the same time in some of the sites.

At Arner, a large group of at least 50 Red-winged Blackbirds (*Agelaius phoeniceus* (L.)) were active within a large patch of 517 plants. One blackbird swooped down, removed a berry and returned to the canopy above. Numerous other birds were flying back and forth, from the canopy to the patch, over a period of about five minutes, and 30 to 50 berries present before the birds arrived were gone after they departed. Although not extensive, these observations suggest that neither pollination nor dispersal are limiting to population growth.

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private landowners kindly allowed us to work on their properties.

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Rare Plants from Islands in Lake Winnipeg, Manitoba

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Staniforth, Richard J., and Jacques Tardif. 2000. Rare plants from islands in Lake Winnipeg, Manitoba. *Canadian Field-Naturalist* 114(3): 501–502.

We report a disjunct colony of the provincially rare *Dulichium arundinaceum* (Three-way Sedge) from an isolated bog on Black Island in Lake Winnipeg, Manitoba. Occurrences of several provincially rare, vascular plant species on Lake Winnipeg islands suggests that they may be ecological refuges for rare plants. The islands are in need of careful botanical study.

Key Words: Three-way Sedge, *Dulichium arundinaceum*, Lake Winnipeg, Manitoba, islands, rare plants.

In August 1999, we discovered a disjunct population of *Dulichium arundinaceum* (L.) Britton, (Three-way sedge, Cyperaceae) on Black Island in Lake Winnipeg, Manitoba (51°12.2' N 96° 27.8' W). This species is rare in Manitoba (White and Johnson 1980) and the new site is over 100 km northwest of other locations. The location lies within Hecla Island-Grindstone Point Provincial Park, Manitoba. An examination of herbaria at the Manitoba Museum of Man and Nature (MMMN), University of Winnipeg (UWPG) and University of Manitoba (WIN) revealed seven previous collections. These were all from mainland sites within the Whiteshell and Nopiming Provincial Parks and closer to the Manitoba-Ontario boundary. Apart from these Manitoban records, the species is absent from the prairie provinces (Scoggan 1978). In eastern Canada, its range extends from western Ontario to Newfoundland (Scoggan 1978), but it is also found in British Columbia. *Dulichium arundinaceum* is widespread in the United States (Scoggan 1978).

On Black Island, the population consisted of at least 100 stems and was found in a bog around an unnamed lake in the centre of the island. The colony may have been more extensive than we realized at the time of collection because we examined only a small area adjacent to its northern outflow. The plants were in association with bog/fen species such as: *Andromeda glaucophylla* (Bog Rosemary), *Betula glandulosa* var. *glandulifera* (Bog Birch), *Calla palustris* (Water Arum), *Carex aquatilis* (Water Sedge), *Carex gracillima* (Graceful Sedge), *Drosera rotundifolia* (Round-leaved Sundew), *Larix laricina* (Tamarack), *Ledum groenlandicum* (Com-

mon Labrador Tea), *Picea mariana* (Black Spruce), *Potentilla palustris* (Marsh Cinquefoil), *Salix pedicellaris* (Bog Willow), *Smilacina trifolia* (Three-leaved False Solomon's-seal), *Sphagnum fuscum* (Rusty Peat Moss), *Sphagnum warnstorffii* (Warnstorff's Peat Moss), *Typha latifolia* (Common Cattail), *Vaccinium oxycoccus* (Small Bog Cranberry). Voucher specimens of *Dulichium arundinaceum* have been placed in the herbaria of the University of Winnipeg (UWPG) and the Manitoba Museum of Man and Nature (MMMN).

Other species which are provincially rare, or which are disjunct, have been reported solely or more commonly on islands in Lake Winnipeg than on the mainland (Table 1). The five rare species from Black Island all occur in the southeastern quadrant of the island and within an area of approximately 24 km². Each species is near, or at, the western extreme of its range. Islands in Lake Winnipeg are not given a distinct ecodistrict status, but the bog would be classified as "IV.A.1.g -Saturated needle-leaved or microphyllous evergreen dwarf-shrubland" according to The Nature Conservancy Ecology Group (1996) classification scheme used by the Manitoba Conservation Data Centre (Greenall 1966). Black Island vegetation falls within the Manitoba Lowlands Section of the Boreal Forest Region (Rowe 1972).

Frego and Staniforth (1986) considered disjunct populations of southern or western species in other parts of southeast Manitoba, (e.g., *Opuntia fragilis*, Brittle Prickly-pear) to be hypsithermal relics. Likewise, *Dulichium arundinaceum* may have become isolated by a southward expansion of the

TABLE 1. Provincially rare vascular plants reported from islands in Lake Winnipeg, Manitoba.

Species	Common name	Location	Citation
<i>Calopogon fuberosus</i>	Grass Pink	Hecla Island	White and Johnson (1980)
<i>Dulichium arundinaceum</i>	Three-way Sedge	Black Island	This publication
<i>Eleopharis ovata</i>	Ovoid spike-rush	Hecla Island	White and Johnson (1980)
<i>Epigaea repens</i>	Trailing Arbutus	Black Island	Personal observations, 1999
<i>Lycopodium tristachyum</i>	Ground Cedar	Deer Island	White and Johnson (1980)
<i>Lycopodium tristachyum</i>	Ground Cedar	Black Island	Personal observations, 1999
<i>Pinus resinosa</i>	Red Pine	Black Island	Bell (1881, 1897)
<i>Pinus resinosa</i>	Red Pine	Black Island	Personal observations, 1999
<i>Platanthera lacera</i>	Ragged Fringed-orchid	Hecla Island	White and Johnson (1980)
<i>Pyrola rotundifolia</i>	Round-leaved Wintergreen	Hecla Island	White and Johnson (1980)
<i>Taxus canadensis</i>	Ground Hemlock	Black Island	Personal observations, 1999
<i>Taxus canadensis</i>	Ground Hemlock	Hecla Island	Personal observations, 1999

boreal forest when the climate cooled 4000 years ago, however, there are other possible explanations. For instance there is the possibility of long-distance dispersal by migrating birds or, that some disturbance on the mainland left island populations relatively intact. Isolation of *Dulichium arundinaceum* and other species on islands in Lake Winnipeg is interesting because it introduces the idea that certain plant species may have more chance of persisting on islands than on the mainland when climates change or when disturbances occur. A thorough botanical investigation of islands in Lake Winnipeg might detect other interesting plants and furnish ideas as to why the islands provide a suitable refuge for rare or disjunct species.

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Proximity of White-tailed Deer, *Odocoileus virginianus*, Ranges to Wolf, *Canis lupus*, Pack Homesites

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Nelson, Michael E., and L. David Mech. 2000. Proximity of White-tailed Deer, *Odocoileus virginianus*, ranges to Wolf, *Canis lupus*, pack homesites. *Canadian Field-Naturalist* 114(3): 503-504.

Seven adult female White-tailed Deer (*Odocoileus virginianus*) in northeastern Minnesota lived within 1.8 km of Wolf pack (*Canis lupus*) homesites without vacating their home ranges. Six of these deer and at least three of their fawns survived through the Wolf homesite period.

Key Words: White-tailed Deer, *Odocoileus virginianus*, Wolf, *Canis lupus*, predator-prey relations, predation, Wolf home-site, deer home ranges, Minnesota.

Adult white-tailed Deer (*Odocoileus virginianus*) chased by Wolves (*Canis lupus*) in the dense forests of northeastern Minnesota escape most of the time when chased during winter (Nelson and Mech 1993), and adult does are rarely killed during summer when dispersed on individual summer home ranges (Nelson and Mech 1986). Because Wolf pack territories (Mech 1973) are orders of magnitude larger than an individual deer's home range (Nelson 1979), most deer may encounter Wolves infrequently.

However, deer chased by Wolves often stop running to view their backtrail and only continue fleeing if the Wolves catch up to them (Mech 1970; Nelson and Mech 1993). Furthermore, nearby deer not being chased do not immediately leave the area, and we have even observed fresh deer tracks at 1-day-old kill sites. These observations suggest that deer might not vacate their home ranges when Wolves headquarter near them even though one might expect them to do so to minimize their exposure to Wolves. Nevertheless, it is unknown how deer respond in such situations.

The opportunity to gain insight into this subject arose when a pack of 15 Wolves (three wearing radio-collars) in 1987 established a late summer homesite adjacent to four radio-collared adult does, and another pack of five Wolves (including the radio-collared breeding female) in 1996 denned near three other radio-collared does in northeastern Minnesota, 48°N 92°W (Nelson and Mech 1981, 1987). We located the four does from the ground daily during fawning in late May and early June and one to two times/week by small aircraft July - September. We similarly located the three does weekly during April-May, daily during 1-14 June, twice daily during 15 June - July, and once/week thereafter. Ground and aerial observations of Wolves and aerial radio-tracking one to two times/week provided the Wolf homesite data. Ground (hand-held antenna) and aerial radio-tracking error was < 2 ha

and 50 m respectively (Hoskinson 1976; Nelson 1979).

Both groups of our radioed does in 1987 and 1996 remained in their summer ranges after wolves established a den or rendezvous site within 0.8-1.8 km of them (Table 1). We observed single fawns with three of the four 1987 deer in August and September. On 25 August we found the chewed collar of one of the deer, a 7-year-old doe, cached in the Wolf homesite. The doe had used an area 0.5 km south of the homesite, and it is uncertain how she died, whether she had moved closer to the homesite, or if Wolves had carried her collar there. This doe had increased her movements during July - August, nearly tripling her range size, suggesting that she had lost her fawn(s) sometime in June (Nelson and Mech 1981). Our three radioed does in 1996 survived throughout the wolf denning period, but we have no information about whether they had fawns during that time.

These findings indicate that forest deer do not necessarily vacate their home ranges when Wolves headquarter within 0.8-1.8 km of them. Our sample of seven deer is too small to analyze survival probabilities, but their proximity to Wolves would suggest some added risk of predation, and perhaps that was a factor in the death of one of them. However, the noteworthy unequivocal observation is that seven does remained on their traditional home ranges despite proximity to Wolf homesites and did not attempt to minimize exposure to the Wolves by moving away.

Acknowledgments

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TABLE 1. Spatial relationships between radioed deer and Wolves in Superior National Forest.

Year	No. Deer	Number of Locations Per Doe	Dates		Number of Wolves	Distance From Deer (km)
			Deer in Home Range	Wolves in Homesite		
1987	4 Does, ≥ 3 Fawns	45	≤ 11 May - > 30 September	~ 18 August - ≥ 9 September	≥ 6 Adults 6 Pups ¹	1.0-1.8
1996	3 Does, ? Fawns	53-69	1 April - ≥ 28 July	15 April - 26 July	5 Adults ≥ 2 Pups	0.8-1.5

¹At least 15 Wolves based on an observation on 17 December.

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A Record Large Wolf, *Canis lupus*, Pack in Minnesota

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Mech, L. David. 2000. A record large Wolf, *Canis lupus*, pack in Minnesota. *Canadian Field Naturalist* 114(3): 504-505.

This report documents a pack of 22-23 Wolves (*Canis lupus*) in central Minnesota. This is larger than the largest pack previously observed on the mainland in the midwestern U.S. during 650 wolf pack-years. Because this record-large pack preyed on White-tailed Deer (*Odocoileus virginianus*), one of the Wolf's smaller prey, it is evidence that pack size and prey size are not tightly related. It also indicates the size that Wolf packs can attain in the area if fully protected from human persecution.

Key Words: Wolf, *Canis lupus*, pack size, prey, White-tailed Deer, *Odocoileus virginianus*, Moose, *Alces alces*, Minnesota.

Wolf (*Canis lupus*) pack sizes are of interest for several reasons. One is because of the possible relationship between pack size and prey size; packs preying on Moose (*Alces alces*), for example, are often much larger than those feeding primarily on White-tailed Deer (*Odocoileus virginianus*) (Mech 1970). Second, documenting extremes is useful to a full understanding of a species' basic life history. Third, as Wolf populations, which have been legally protected since 1974 in the contiguous 48 states, recover in new areas inhabited by humans, the potential sizes of their packs is of importance to resource managers seeking to minimize conflicts with humans. Wolves in Minnesota feed mostly on

deer, and average pack sizes are relatively small (Mech and Frenzel 1971; Van Ballenberghe et al. 1975; Fritts and Mech 1981; Mech 1986; Fuller 1989). This note documents a record-sized pack.

Results

A pack of 23 Wolves was observed on 19 September 1998 by Jack E. Stewart of Ogilvie, Minnesota, in Pine County 8 km WNW of the town of Rutledge (46° 18'N; 92° 58'W). Some 7 km northwest of Stewart's observation, Ms. Shirley Kwapick of Minneapolis, Minnesota counted a pack of 22 Wolves crossing the driveway of her summer camp about 25 November 1998. Stewart (1999) recounted

his observation in a general way in a popular article. I interviewed Stewart and Kwapick to document the details of their observations and to record them here for the scientific community, along with a discussion of their significance. I also confirmed the presence of an active Wolf den the following year within 1.6 km of the Stewart observation.

Discussion

Of 410 Wolf pack years recorded for Minnesota, the largest pack documented in the state contained 17 members (Stenlund 1955; Van Ballenberghe et al. 1975; Fritts and Mech 1981; Mech 1986 and unpublished; Fuller 1989). The largest pack in adjoining Wisconsin (240 pack years) was 10 (Wisconsin Department of Natural Resources 1999). Olson (1938) claimed that Minnesota Wolf packs contained up to 30 wolves but gave no evidence, and he cited trappers who told him they had seen packs of 18 and 20.

Thus this observation of 22–23 Wolves represents a significant divergence from most mainland Midwestern Wolf packs, even those living where the primary prey is Moose (*Alces alces*). The area where these observations were made is many km from the nearest Moose range. Deer constitute the only large ungulate in the area other than livestock. Only seldom have Wolves killed livestock in the area. Thus this large Wolf pack had to be living primarily on deer.

The sizes of most Wolf packs are assessed in winter when they can be aerially observed. Because of mortality and dispersal over winter, the largest pack sizes are usually seen in December (Mech 1986). Thus a November observation, such as reported here is not a completely fair comparison to previous records. On the other hand, the observation of 22 was made only 1 week before December, so it is reasonably comparable with others and tends to confirm the 23 seen in September.

The fact that this record-large Wolf pack inhabited an area of deer rather than of larger prey is at least some evidence that any relationship between prey size and pack size (Mech 1970; Nudds 1978) is not

tight. In addition, such a large pack indicates the potential size of packs that Wolves in a recovering population can reach when protected from human persecution.

Acknowledgments

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Aggressive Behavior Exhibited by a Swift Fox, *Vulpes velox*

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Kamler, Jan F., Warren B. Ballard, and Kevin Mote. 2000. Aggressive behavior exhibited by a Swift Fox, *Vulpes velox*. Canadian Field-Naturalist 114(3): 506.

While live-trapping Swift Foxes (*Vulpes velox*) we observed a juvenile male Swift Fox that exhibited aggressive behavior while protecting a juvenile female Swift Fox that had been captured in a wire box trap. Although Swift Foxes are not normally known to be aggressive, our observation demonstrates their ability to exhibit this behavior when protecting other family members.

Key Words: Swift Fox, *Vulpes velox*, aggressive behavior, protective behavior, Texas.

Swift Foxes (*Vulpes velox*) are generally considered one of the least aggressive of the canid species in North America (Stewart 1999). This may contribute to their vulnerability to larger canids, as predation by Coyotes (*Canis latrans*) was found to be the major cause of Swift Fox mortality in several areas of North America (Laurion 1988; Covell 1992; Sovada et al. 1998). The more aggressive Red Fox (*Vulpes vulpes*) may also dominate and out-compete Swift Foxes (Sovada et al. 1998; Stewart 1999).

Despite the usual nature of Swift Foxes, we observed a juvenile male Swift Fox exhibit aggressive behavior we interpreted as an effort to protect a juvenile female Swift Fox that had been captured in a wire box trap. This observation was made on 17 October 1998, at Rita Blanca National Grasslands (36°22'N, 102°40'W) in Dallam County, Texas. We were trapping Swift Foxes in wire box traps and placing radio-collars on them as part of a study to determine the effects of Coyotes on the ecology of Swift Foxes in the Texas panhandle.

In a vehicle, Kamler approached a wire box trap that had recaptured a juvenile female Swift Fox. The female Swift Fox already had a radio-collar on her, however, another fox that did not have a radio-collar was laying beside her on the outside of the trap. Kamler left and returned shortly thereafter with another box trap to attempt to capture the unmarked fox. Kamler stopped the vehicle approximately 10 m from the captured fox and the unmarked fox quickly ran a short distance away. Kamler got out of the vehicle to place the second box trap next to the captured fox. As he walked towards the captured fox, the unmarked fox ran aggressively towards him. It continued to stay between him and the captured fox, and would walk towards him every time he walked towards the captured fox. Yelling and waving hands caused the unmarked fox to run a short distance

away, however, each time Kamler attempted to approach the captured fox, it would run towards him and attempt to "nip" his feet. After continuous yelling, he was able to set the second trap and capture the unmarked fox. It was a juvenile male that was similar in size to the recaptured juvenile female (2.3 and 2.0 kg, respectively), and they were probably siblings.

Subsequent radio-tracking revealed that both juvenile Swift Foxes remained on the study site, although they rarely were located together. The juvenile male was killed by a Coyote five months after his capture, and the juvenile female continues to be monitored on the study site.

Our observation suggests that Swift Foxes can occasionally be aggressive, particularly when protecting presumed family members.

Acknowledgments

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Predation of a Denning Black Bear, *Ursus americanus*, by a Grizzly Bear, *U. arctos*

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Boyd, Diane K., and Edgar E. Heger. 2000. Predation of a Denning Black Bear, *Ursus americanus*, by a Grizzly Bear, *Ursus arctos*. Canadian Field-Naturalist 114(3): 507–508.

The site where a Grizzly Bear (*Ursus arctos*) preyed upon a denning Black Bear (*Ursus americanus*) was investigated in northwest Montana. The Grizzly Bear excavated, killed, and consumed the Black Bear.

Key Words: Black Bear, *Ursus americanus*, Grizzly Bear, *Ursus arctos*, denning, predation.

Interspecific predation on Black Bears (*Ursus americanus*) is rarely observed or reported but may be a frequent occurrence, particularly when they are sympatric with Grizzly Bears (*U. arctos*) (Miller 1985). Wolves (*Canis lupus*) have killed denning Black Bears (Horejsi et al. 1984; Paquet and Carbyn 1986; Rogers and Mech 1981) and Grizzly Bears have killed Black Bears in non-denning situations (Jonkel and Cowen 1971; Boertje et al. 1988). Furthermore, several authors reported incidents of cannibalism among Grizzly Bears and among Black Bears (Troyer and Hensel 1962; Jonkel and Cowen 1971; Craighead 1972; Glenn et al. 1976; Pearson 1976; Reynolds et al. 1976; Payne 1978; Tietje et al. 1986). While reviewing the literature, we found only one report of predation by a Grizzly Bear on a denning Black Bear (Smith and Follmann 1993). Ross et al. (1988) reported predation of two Black Bear cubs by Grizzly Bears in late October, but whether the cubs were killed in or near a den was not determined.

In November 1997, we documented the predation of a denning Black Bear by a Grizzly Bear 15 miles north of Polebridge, Montana (48° 56' N, 114° 26' W). Bloodied snow approximately 25 cm across was observed on 11 November at the base of a 20 year-old, 12 m diameter pile of logging debris. The freshly bloodied patch was on top of snow that had fallen 24 hr earlier, and tracking conditions were excellent. A drag trail with fresh Grizzly Bear tracks led away from the slash pile and into a dense, mixed conifer forest 60 m away. The Grizzly Bear's hind foot tracks measured 23 cm from the back of the heel pad to the front of the toe pads, excluding claws, and was 13 cm wide. The tracks of its front foot measured 13 cm wide, and 11.4 cm from the back of the heel pad to the front of the toe pads, excluding claws. EEH approached the forest edge and peered into the spruce thicket unaware of the bear's immediate presence. The Grizzly Bear charged but was deterred by pepper spray (oleoresin capsicum) at a distance of 7 m. Estimated body weight (115–140 kg) and track size suggested the Grizzly Bear was an adult female or subadult male.

By examining the evidence at the site, we determined that a small Black Bear had denned in the slash pile and entered the den through a 56-cm by 46-cm hole. A Grizzly Bear detected the denning Black Bear and removed the roof of the den to access it. The Grizzly removed the Black Bear, dragged it 80 m into the forest, and consumed it. The fresh pattern of the blood splatters and signs of struggle suggested the Black Bear was alive when the Grizzly Bear encountered it in the den. The Grizzly Bear completely consumed the Black Bear, leaving only a few bone fragments, stomach contents and some hair. The Grizzly Bear remained in the area for two weeks, revisiting the remains of the carcass and the den site. Little sign of other scavengers was observed in the area. The size of the femur remnants indicated the Black Bear was probably a yearling. A small (< 45 kg) Black Bear had been seen walking within 200 m of the slash pile six weeks earlier.

Interspecific predation may influence resource partitioning between Grizzly Bears and Black Bears as well as the population dynamics and behavior of both species of bear (Smith and Follmann 1993). However, the interspecific predation reported herein appeared to be opportunistic predation by the Grizzly Bear immediately prior to denning.

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News and Comment

Notices

The 122nd Annual Business Meeting of The Ottawa Field-Naturalists' Club: 9 January 2001

The 122nd Annual Business Meeting of The Ottawa Field-Naturalists' Club will be held in the auditorium of the Canadian Museum of Nature, McLeod and Metcalfe streets, Ottawa, on Tuesday 9 January 2001 at 7:30 p.m. (19:30 h). The Council for 2001 will be elected at this meeting and a

brief review of the activities during 2000 will be given, as well as a statement of the Club's finances.

JOHN MARTENS
Recording Secretary

Call for Nominations: Ottawa Field-Naturalists' Club 2000 Awards

Nominations are requested from members of The Ottawa Field-Naturalists' Club for the following: Honorary Membership, Member of the Year, George McGee Service Award Citation, Conservation, and the Anne Hanes Natural History Award. Descriptions of these awards appeared in *The Canadian Field-Naturalist* 113(4). With the exception

of nominations for Honorary Member, all nominees must be members in good standing.

STEPHEN DARBYSHIRE
Chair, Awards Committee

Call for Nominations: The Ottawa Field-Naturalists' Club 2001 Council

Candidates for Council may be nominated by any member of The Ottawa Field-Naturalists' Club. Nominations require the signature of the nominator and a statement of willingness to serve in the position for which nominated by the nominee.

Some relevant background information on the nominee should also be provided.

COLIN GASKELL
Chair, Nominating Committee

Biodiversity: Journal of Life on Earth 1(2)

1(2) May 2000 contains: FOCUS: A network of spiders (Charles Dondale) — Costa Rica's area of conservation Guanacaste: A long march to survival through non-damaging biodevelopment (Daniel H. Janzen) — Living off the grid: How to survive ice storms and other natural disasters — Seahorse chaos: the importance of taxonomy to conservation (Sara A. Lourie) — ... And yet, there is hope. From a century of loss to a century of environmental gains (Maritta R. von Bieberstein Koch-Weser) — EDITOR'S CORNER (The beauty of biodiversity) — SPECIES BY SPECIES (Pineapple, *Ananas comosus*) — NEWS DIGEST — FROM TROPICAL CON-

SERVANCY (Stewards of the living earth) — BOOK REVIEWS — ANNOUNCEMENTS.

Biodiversity is published by the Tropical Conservancy, 94 Four Seasons Drive, Ottawa, Ontario K2E 7S1, Canada. The Editor-in-Chief is D. E. McAllister, and the managing editor is Catherine Ripley. Subscription rates for a year (4 issues) are individuals \$25 and institutions \$50. Canadian orders should add 7% GST, foreign orders should be paid in U.S. funds. Special rates are available for developing countries). Additional information on the journal is available at the web site: <http://www.synapse.net/~tropical/publication.htm>.

Sea Wind: Bulletin of Ocean Voice International 14(1), 14(2), 14(3)

14(1) January-March 2000, 40 pages, contains: Environmental education for fisherfolk communities in the Philippines — A hierarchical marine ecosystem classification completed for Canada's west coast — Reminiscences of a New Zealand greenie — Sea skaters: Dancers on the sea surface — Ocean Voice International Annual General Meeting — Annual Report of Ocean Voice International for 1999-2000 — Quotes — Biodiversity Course on West Coast of Canada — Sea News — Book Nook.

14(2) April-June 2000, 36 pages, contains: Dedication to

the small-scale fisher — A flyfishing ecology — Arnie Narcisse, First Nation recipient of the Roderick Haig-Brown Award — Women & fisheries — Mounting seaweeds for fun or a livelihood — The future of Iceland: Eco-line fishing for 1,100 years — Sea News — Book Nook — Publishing Sea Wind.

14(3) July-August 2000, 36 pages, contains: The Marine Stewardship Council: Achieving sustainable fisheries through consumer choice — Conserving deepsea corals — The Earth Charter — Environment & bulk water export

under free trade — Fisheries and civil governance — A poem: *Anguilla rostrata* — Saving the Fraser River and its salmon — Sewage in the seas from the Canary Islands to Canada — Kids' Korner: Shells — Sea News — Book Nook.

Sea Wind is a publication of Ocean Voice International and is edited by Donald E. McAllister (e-mail: mcall@

superaje.com) and is available through subscription or membership from Voice International Inc., 2255 Carling Avenue, Suite 400, Ottawa, Ontario K2B 1A6, Canada; phone (613) 721-4541; fax (613) 721-4562; Angela Jellett, Executive Director at: e-mail: <ovi@cyberus.ca>; home page: <http://www.ovi.ca>

Froglog: Newsletter of the Declining Amphibian Populations Task Force (39, 40, 41)

Number 39, June 2000, contains: The Negros Cave Frog is critically endangered (A. C. Alcalá) — Chytrid fungi identified from dying frogs in New Zealand (Phil Bishop) — Crocodile salamanders of the eastern Himalayas (Debjani Roy & Sri Aurobindo) — The rise and fall of a population of *Hyla boans*: reproduction in a Neotropical Gladiator Frog (Abstract from 1999 *Journal of Herpetology* 33(4): 647–656) — Amphibian "death kits" (Lauren J. Livo and Mark S. Jones) — Progress report of the Southern African Frog Atlas Project (Les Minter, James Harrison, and Marius Burger) — Frog Shorts — Tailthought: Do amphibian diseases have wider implications? (Tim Halliday).

Number 40, August 2000, contains: Seed grants 2000 (Tim Halliday) — Evidence of a chytrid fungus infection involved in the decline of the Common Midwife Toad in protected areas of central Spain (Jaime Bosch, Inigo Martinez-Solano, and Mario Garcia-Paris) — Frog's paradise has gone [Adasibe forest area, formerly Perinet, Madagascar] (Denis Vallan) — Amphibian conservation at

the Detroit Zoological Institute (Andy Snider and Kevin Zippel) — Seychelles Amphibia: a mixture of secure and declining species (Justin Gerlach) — Froglog shorts [new chair: James Hanken, professor in Department of Organismic and Evolutionary Biology at Harvard University and curator of herpetology in the Museum of Comparative Zoology] — Publications of Interest.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force of The World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, The Smithsonian Institution, and Harvard University). The newsletter is Edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA. *Froglog* can be accessed at <http://www2.open.ac.uk/biology/froglog/>

Marine Turtle Newsletter (88 & 89)

Number 88, April 2000, 36 pages, contains: EDITORIAL: Listing to the elders — ARTICLES: Newly documented epibiont species from nesting Loggerhead Sea Turtles (*Caretta caretta*) in Georgia, USA — Unusual tumors in three Loggerhead Sea Turtles (*Caretta caretta*) stranded in the Canary Islands, Spain — Sea turtles in Kuwait after the Gulf War — NOTES: Records of *Caretta caretta* in Mauritania — Liberia sea turtle project — Sea turtles in Myanmar: past and present — Earliest record of Gahirmatha turtles — LETTERS TO THE EDITORS: Clarification of Kemp's Ridley nesting numbers — Cruelty to sea turtles on Corn Island/Nicaragua — c 70,000.00 (about US \$19) saves life of a Leatherback Turtle in Ghana — MEETING REPORTS — ANNOUNCEMENTS — NEWS & LEGAL BRIEFS, RECENT PUBLICATIONS.

Number 89, July 2000, 32 pages, contains: GUEST EDITORIAL: Obstacles to objectivity: First impressions of a CITES CoP — ARTICLES: Community-based research and its application to sea turtle conservation in Bahia Magdalena, BCS, Mexico — Update on the nesting population of

Loggerhead Sea Turtles in Praia do Forte, Bahia, Brazil — First documentation of fibropapillomas verified by histopathology in *Eretmochelys imbricata* — NOTES: Mangroves in the diet of captive reared juvenile Loggerhead Turtle: An example of habituation? — Early report of fibropapilloma from St. Croix, USVI — MEETING REPORTS — ANNOUNCEMENTS — NEWS & LEGAL BRIEFS, RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; fax +1 978 582 6279. MTN website is: <<http://www.seaturtle.org/mtn/>>

Canadian Species at Risk May 2000

The latest Committee on the Status of Endangered Wildlife in Canada (COSEWIC) listing *Canadian Species at Risk May 2000*, 19 pages, gives not only the new designations from spring annual meeting but also reviews current ranks of all previously considered species. The list is in three parts: (1) gives all species designated in the five Risk categories: Extinct, Extirpated, Endangered, Threatened and Special Concern (a renaming of initial "Rare", and subsequent "Vulnerable" category); and two non-risk categories: Not at Risk (evaluated and found not to merit designation in one of risk categories — formerly "Not in Any

Category" and "No Designation Required") and Data Deficient (formerly "Indeterminate" and "Insufficient Scientific Information on which to Base a Designation").

A total of 513 "species" [species, subspecies or distinct populations] are listed covering COSEWIC activity since it was created in 1977 for nine groupings: amphibians, birds, fish, lepidopterans, lichens, mammals, mosses, vascular plants, reptiles. In all designations give 353 at risk, 136 not at risk, and 24 data deficient for forms evaluated on the basis of status reports. Those newly considered or re-evaluated this year comprise 141 of the total.

1999-2000 Annual Report: Recovery of Nationally Endangered Wildlife — Rescuing Species from Extinction

Presented in 16 pages English and 16 French are a Report from the Chair [David Brackett], Highlights [47 recovery teams in place, 17 approved recovery plans, 3 waiting approval, \$14.4 million expended on recovery (salaries + expenses), employment equivalent to about 100 people working full-time, volunteer effort reported as about 16 people working full-time, 120 organizations made financial contributions], outline of the National Recovery Process, and Status of Recovery Planning (10 page table detailing 47 species), two-page list of Financial Contributors, 1 page list and pie diagram of Funding per Species and financial support given by category [29.18 % from traditional "NGOs": Non-Government Organizations; such as the World Wildlife Fund Canada, Canadian Nature Federation, Canadian

Wildlife Federation] and only 2.75 and 2.10% from museums/zoos/aquaria and from universities, respectively.

This report was produced for the Canadian Endangered Species Conservation Council by the Canadian Wildlife Service of Environment Canada in cooperation with the provinces, territories, Fisheries and Oceans Canada and Parks Canada Agency. It is complemented by the RECOVERY web site (www.cws-scf.ec.gc.ca/es/recovery.html). Additional information is available by e-mail: RENEW-RESCAPE@ec.gc.ca; phone 819-994-2365; fax 019-994-3684. The report is available in either english or french from Canadian Wildlife Service, Environment Canada, Ottawa, Ontario, K1A 0H3 and is accessible at www.cws-scf.ec.gc.ca/es/recovery/archive.html

Newsletter of the Canadian Amphibian and Reptile Conservation Network 4(2)

The Summer 2000 issue is entirely concerned with the 5th Annual Meeting held at Penticton, British Columbia 22-25 September 2000 which focused on three symposia: Volunteer monitoring programs; Wetland Conservation Issues; Important Amphibian and Reptile Areas (see selection criteria at www.cciw.ca/ecowatch/dapcan/important_areas/intro.html

Also noted is the Digital Frog International Inc. and Canadian Amphibian and Reptile Conservation Network

scholarship to support research and conservation of amphibians in Canada to be announced at the Penticton meeting.

Membership in The Canadian Amphibian and Reptile Conservation Network/Reseau Canadien de Conservation des Amphibiens et des Reptiles is \$16 per year for non-students and \$10 for students. Checks or money orders payable to CARCN may be sent to Bruce Pauli/ CRCN c/o National Wildlife Research Centre, Hull, Quebec K1A 0H3, Canada.

RENEW Report (19): Vancouver Island Marmot

The National Recovery Plan for the Vancouver Island Marmot (*Marmota vancouverensis*) is now available as RENEW Report (19), 34 pages, from RENEW Secretariat

c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada [See also RECOVERY web site: <http://www.cws-scf.ec.gc.ca/es/recovef.html>]

Amphipacifica 2(4)

With 2(4): 1-118, *Amphipacifica: Journal of Aquatic Systematic Biology* has resumed publication after suspension since May 1997. Journal founder Dr. E. L. Bousfield is Managing Editor and Dr. D. G. Cook has taken the role of Technical Editor. The journal is registered at the National Library of Canada as ISSN Number 1189-9905. The contents of 2(4) are: Editorial [Welcome back to *Amphipacifica*, page 1] — The species of *Lysmata* (Caridea: Hippolytidae) from the Eastern Pacific Ocean [Mary K. Wicksten, pages 3-22] — The amphipod family Melitidae on the Pacific coast of North America. Part II. The *Maera-Ceradocus* complex [Traudl Krapp-Schickel and Norma E. Jarrett, pages 23-61] — The Whale-Lice

(Amphipoda: Cyamidae) of the Northeastern Pacific Region [Leo Margolis, T. E. McDonald, and E. L. Bousfield, pages 63-117].

Subscriptions (4 numbers per volume) are renewable at \$50 (Can) or \$40 (US) including surface postage. Author charges are initially \$25 per printed page, subject to change. Instructions to authors on the scope of contributions are given in the lead editorial in the current issue, and instruction on manuscript preparation is outlined on the inside back cover. For further information contact Dr. E. L. Bousfield, Managing Editor, 1710-1275 Richmond Rd., Ottawa, ON, CANADA K2B 8E3 e-mail: elbousf@magma.ca

Amphibian Voice 10(3)

The Fall 2000 issue of the newsletter of the Adopt-A-Pond Wetland Conservation Program sponsored by the Toronto Zoo (see: www.toronto.zoo.com/adoptapond; or write Adopt-A-Pond, Toronto Zoo, 361 Old Finch Avenue, Scarborough, Ontario M1B 5K7; fax (416) 392-4979; or e-mail: aap@zoo.metrotor.on.ca). It is promoted as "a student/teacher and community newsletter, distributed to schools and communities participating in the Adopt-A-Pond programme, to assist with their efforts to conserve amphibians and wetland habitats", and cheerily invites these readers to send in stories, drawings, and photographs which the editors may "hoppily" include in future issues. The programme is supported the Toronto Zoo Foundation, Youth Canada Works, and the Canadian Museums Association, and the newsletter is edited by Diana Teal, Adopt-A-Pond Coordinator, and Bob Johnson, Curator of Reptiles and Amphibians at the Toronto Zoo. The current issue deals with the Oak Ridges Moraine which lies on the north side of Metro Toronto, and stretches 160 kilometres from the Niagara Escarpment to below the east end of Rice Lake. It includes an article by Natalie Helferty, "Amphibians of Oak Ridges Moraine", stressing that rare

Ontario species such as Jefferson Salamander and Pickerel Frog occur there. Lisa Montgomery and Joelle Vandermeer, in "A Giant Sponge?" point out that the importance of this moraine lies both in its extent and its composition. It runs through 8 regions and 26 municipalities, and originated from the meeting of glaciers which left, when they receded, a great ridge of sand and gravel, dotted each year with temporary spring (vernal) ponds. The ridge soaks up precipitation, filters the water to storage deep underground in aquifers, and slowly releases water to over 65 brooks, streams and rivers which run into lakes Simcoe, Scugog and Ontario, feeding 15 Ontario watersheds. Diana Teal in "Vernal Pools on the Moraine" further stresses special importance of its seasonally flooded ephemeral wetlands to those salamanders and frogs that exclusively or facultatively depend on such temporary (and therefore fishless) habitat for high rates of egg and larval survival. Additional information links to concerned conservation groups are included for The Federation of Ontario Naturalists (www.ontarionature.org; e-mail: info@ontario.org) and the STORM Coalition (www.stormco.org; e-mail: info@stormco.org).

FRANCIS R. COOK

Minutes of the 121st Annual Business Meeting of The Ottawa Field-Naturalists' Club, 12 January 2000

Place and Time: Canadian Museum of Nature, Ottawa, Ontario, 7:30 p.m.
Chairperson: Dave Moore, President
Attendance: Thirty-six persons attended the meeting.

Attendees spent the first half hour reviewing the minutes of the previous meeting, the Treasurer's Report and the Reports of Committees. The meeting was called to order at 8:00 p.m.

1. Minutes of the Previous Meeting

Moved by Colin Gaskell (2nd by Fenja Brodo) that the minutes be accepted.

(Motion Carried)

2. Business Arising from the Minutes

There was no business arising from the minutes.

3. Communications Relating to the Annual Business Meeting

There were no communications relating to the Annual Business Meeting.

4. Treasurer's Report

Moved by Frank Pope (2nd by Eleanor Zurbrigg) that the report be accepted.

(Motion Carried)

5. Committee Reports

Dave introduced each of the reports and asked for comments and questions.

Moved by S. Darbyshire (2nd by Bev McBride) that the Awards Committee Report be accepted.

(Motion Carried)

Moved by Bev McBride (2nd Fenja Brodo) that the Birds Committee Report be accepted. It was pointed out that this year's seedathon would be led by Robert Bracken.

(Motion Carried)

Moved by Alan German (2nd by Sandy Garland) that the Computer Management Committee Report be accepted.

(Motion Carried)

Moved by Frank Pope (2nd Phillip Martin) that the Conservation Committee's Report be accepted.

(Motion Carried)

Moved by Betty Campbell (2nd David Crombie) that the Education & Publicity Committee Report be accepted as amended. Second sentence of report should read "slide shows"

(Motion Carried)

Moved by Phillip Martin (2nd Colin Gaskell) that the Excursions & Lectures Committee Report be accepted. The Committee was asked to consider organizing a trip to the Biodome in Montreal and to the annual goose festival at Plaisance, Quebec.

Moved by Dave Moore (2nd Dave Smythe) that the Executive Committee Report be accepted.

(Motion Carried)

Moved by Frank Pope (2nd Terry Higgins) that the Finance Committee Report be accepted.

(Motion Carried)

Moved by Sandy Garland (2nd David Hobden) that the Fletcher Wildlife Garden Committee Report be accepted.

(Motion Carried)

Moved by Barbara Gaertner (2nd Frank Pope) that the Macoun Field Club Committee Report be accepted.

(Motion Carried)

Moved by Dave Smythe (2nd Alan German) that the Membership Committee Report be accepted.

(Motion Carried)

Moved by Ron Bedford (2nd Bill Cody) that the Publications Committee Report be accepted as amended. Authors of *Lichens of North America* to include S. Sharnoff.

(Motion Carried)

6. Nomination of the Auditor

Frank Pope moved (2nd by David Burgess) that Janet Gehr continue as Auditor for another year.

(Motion Carried)

7. Report of the Nominating Committee

The Committee recommended the following list of candidates for the 2000 Council (new members are indicated by an asterisk):

President	Eleanor Zurbrigg
Vice-President	Roy John*
Recording Secretary	John Martens
Treasurer	Frank Pope
Other members:	
Ken Allison*	David Hobden
Ronald Bedford	Philip Martin
Fenja Brodo	Beverly McBride
William Cody	David W. Moore
Francis Cook	Robert Roach
Sarah Coulber*	Stanley Rosenbaum
Ellaine Dickson	Dave Smythe
Barbara Gaertner	James Sutton
Anthony Halliday	Dorothy White
Terry Higgins*	

Two members of the 1999 Council decided not to stand for re-election: Colin Bowen and Garry McNulty. Frank Pope thanked both of these members for their contributions to the 1999 Council.

It was moved by Colin Gaskell (2nd by Eleanor Zurbrigg) that the proposed slate be accepted.

(Motion Carried)

7. New Business

Claudia Burns recommended that the Club make an effort to be more accessible to new members

by providing a general exchange of information at the start of the monthly meetings. Council was urged to have members present at the monthly meetings in order to answer questions from the general membership. Stephen Darbyshire suggested that each of the committees should undertake to make periodic reports to members via *Trail & Landscape*. Sandy Garland proposed that the annual reports of the various committees be posted on the Club's web site.

8. Presentation by the Membership Committee

Dan Brunton gave a presentation of the Club's history pointing out the important contributions made by the Club's founders and subsequent leaders. As a special treat, he had several copies of the Club's earlier publications showing how these have evolved over the years.

9. Adjournment

Moved by David Burgess (2nd Irwin Brodo) that the meeting be adjourned at 9:42 p.m. Motion carried. Dave Moore invited members to have some coffee.

GARRY McNULTY
Recording Secretary

The Ottawa Field Naturalists' Club Committee Reports for 1999

Awards Committee

The following awards were presented at the Annual Soiree, held on 23 April 1999.

MEMBER OF THE YEAR AWARD. **Robina Bennett** for her unflinching efforts at many of the Club's activities including the Excursions & Lectures Committee, monthly meetings, leading field trips, the Fletcher Wildlife Garden. She is one of the most dependable workers the Club has.

CONSERVATION AWARD FOR MEMBER. **Ewen Todd** for his many years of work on the Conservation Committee and other committees concerned with conservation issues. Ewen often represented the OFNC on various community advisory and stake-holder groups.

CONSERVATION AWARD FOR NON-MEMBER. **Jean Langlois** for his work with the Ottawa Valley Chapter of CPWAS and his work towards the protection of Gattineau Park.

HONORARY MEMBER. **Francis Cook** for his many years as CFN editor, his many years of leadership and excellence in Canadian herpetology and his many years of service on COSEWIC.

Since the original could not be located after extensive searches, electronic copies of Brenda Carter's great horned owl (*Trail and Landscape* volume 1, number 2) were prepared and versions in various formats were put on CD-ROM and distributed to key committees.

The wording and criteria of the OFNC awards (excluding Honorary Member) were examined and re-written. After approval by the Council, an article with the new wording

and some explanation of each award was published in *Trail & Landscape* (33: 162–167), along with an update of the awards history. New nomination forms were designed and prepared for mailing as a centre insert in *Trail & Landscape*.

A certificate of appreciation was designed to formally thank members and non-members for their help in Club activities. These certificates are to be printed on an *ad hoc* basis by the Awards Committee as requested by the Council and will be signed by the President.

STEPHEN DARBYSHIRE

Birds Committee

The Committee continued its regular activities such as; the Fall and Christmas Bird Counts, maintaining the Bird Status Line and The Rare Bird Alert and the operation of the Club bird feeder program through funds raised by the 1998 Seedathon. The Committee also participated in the organization and the competition of the Taverner Cup birding challenge. Members continued to review rare bird reports and organize lectures to help improve birding skills of club members. Again this year, the Committee participated with the Ontario Ministry of Natural Resources and the Canadian Peregrine Foundation in the now annual Peregrine Falcon Watch. A member of the committee also gave a talk to another naturalists club on the Peregrine Falcon Watch. The Committee has also been active in supplying birding information to the Club's website.

COLIN BOWEN

Computer Management Committee

Work continues to enhance the Club's web site. Usage of the site has increased substantially in the last year. This site provides a vivid and up-to-date presentation of the whole range of activities undertaken by the Club, as well as related activities in the area. There are a number of individuals who have joined the Club as a result of their surfing the site. As well, non-members are purchasing club publications listed on the site. We have also revived the National Capital FreeNet page which will provide basic information about the OFNC and provide a pointer to the main web site.

The Committee's next web related project will be to explore our options with a view to obtaining a web Domain Name. This will establish an independent identity for the club on the Internet and provide a cost effective and more reliable way for people to find our site.

Software has been purchased to enhance the flexibility of the membership database. It will allow the database manager to add new information and create reports without the need for a dBASE programmer to be involved. This membership program has been expanded this year to begin to capture member's e-mail addresses as they renew memberships.

Finally, we addressed the Y2K issue. Each of the Club's computers were tested by a member of the Committee. While the tests went well, this issue will require ongoing monitoring.

JAMES SUTTON

Conservation Committee

The Petrie Island brief, and our activities in cooperation with the Friends of Petrie Island, have assisted the Regional Municipality's planning staff and the City of Cumberland in preparing a draft report that designates most of the island as an ecologically sensitive zone.

Follow-up communications on the Lands For Life process assisted the Partnership for Public Lands in pressing for protection of substantial areas from forestry and mining. Letters were drafted, supporting the nomination of the Rideau River as a (Federal) Heritage River, supporting endangered species legislation, opposing a golf course on NCC land near Leamy Lake, and supporting preservation of the remaining Leitrim Wetlands. Also, a letter (follow-up to 1998) again urged an end to the spring bear hunt. Two financial contributions, each in the amount of \$1,000, were recommended by the committee and approved by council for the preservation of Gillies Grove in Arnprior and the FON campaign to acquire the Manitoulin Island alvar land.

We met with NCC planners, and discussed recreational uses of the Greenbelt, including golf courses.

STAN ROSENBAUM

Education & Publicity

Talks and/or walks were given for the Churchill seniors, Kilian Lodge and Nepean Parks and Recreation. Six OFNC slide shows were organized and duplicated to assist those giving talks. OFNC displays and information were presented at the Carleton Teachers' Federation PD day, Wildlife Week at the Carlingwood Shopping Centre, the Annual OFNC Soirée, National Defence Headquarters, the

Constitution Building and the Ottawa Public Library. The Committee also provided judges, and prizes for the Ottawa Science Fair, coordinated nature walks with the NCC to solicit new members and prepared and distributed notices for monthly meetings.

Sales of club merchandise was approximately \$500. Recruitment of new committee members met with no success despite calls for help at the Annual Business Meeting, the Annual Soirée and advertisements in *Trail & Landscape* and OFNC website.

CHERYL MCJANNET

Excursions & Lectures

The Excursions and Lectures Committee made arrangements for a total of 43 outings during 1999. There were 17 outings to study birds, 6 plants, 4 insects, and 4 to observe amphibians, fungi, geology and astronomy, while another 12 outings were general in nature. The bird outings included two major popular annual excursions to Presqu'île and Derby Hill and the biennial excursion to Point Pelée. Several of these events were organized in conjunction with the Fletcher Wildlife Garden. Our program also included our regular nine monthly meetings at the Canadian Museum of Nature. The Annual Soirée was held, as usual, at the end of April.

PHILIP MARTIN

Executive Committee

The Executive Committee did not meet in 1999.

DAVE MOORE

Finance

The Committee met on three occasions. The audited accounts for 1997/1998 were presented to the Club's December 1998 meeting and were approved at the Club's Annual Business Meeting.

Frank Pope assumed the office of Treasurer. The Committee examined ways to enhance the capacity of the Treasurer's Assistant to provide Committees with up-to-date, "user-friendly" data on expenditures. With the help of an outside consultant a system has been devised whereby such information will be readily available on an ongoing basis for expenditures against budget and the balances available. The system will not operate effectively where Committees have multiple expenditure heads.

The Committee held an initial discussion on possible uses for the Manning bequest. A draft budget for 1999/2000 was presented to Council in September and, after adjustments, accepted at its October meeting. The Committee recommended no change in the membership fee structure.

ANTHONY HALLIDAY

Fletcher Wildlife Garden

The Fletcher Wildlife Garden faced some challenges this year as a number of key members of the Management Committee, including the Chair, were no longer available to continue their unstinting volunteer time. This affected, in particular, the number of special events and the maintenance activity level at the interpretation center. However, for the first time, a student was hired for the summer and kept the interpretation centre open for 10 weeks increasing the opportunities for visits from the public.

A new portable display unit was purchased and a new FWG display mounted on it. In addition to using it at the centre, it was also displayed at Carlingwood Shopping Centre during Wildlife Week. About a half dozen special events were held, including two plant sales in the spring and fall that raised funds for the garden. As well, about six slide talks were given to horticulture and natural history organizations in the Ottawa Valley.

The focus of garden activity this year was on completing the main work of the Backyard Garden and a team of about 10 volunteers met every Friday for planting and maintenance. An interpretative brochure was also produced for the Backyard Garden. Many native trees and shrubs were planted throughout the FWG. To increase awareness of the FWG, boundary signs were installed around the site.

About 2,500 volunteer hours were contributed this year.

PETER HALL

Macoun Field Club

The committee met five times during the year to plan the weekly programs for the children and young people of the Macoun Field Club. In addition to the regular indoor schedule of speakers and natural history workshops, committee members organized and led 19 field trips and 4 camping trips. The Macoun Field Club also participated in the June 19 Leitrim Wetlands Bioblitz.

The previously reported membership gap is moving up through the ranks, so the middle age-group was re-established.

ROBERT LEE

Membership

The distribution of memberships for 1999 is shown in the table (below), with the comparable numbers for 1998 in brackets. These statistics do not include four complimentary

ry memberships awarded to winners of the 1999 Science Fair competition nor the 15 affiliate organizations which receive copies of the Club's publications.

This year the Club awarded an Honorary Membership to Francis R. Cook for his contributions to the Club and to Canadian biology.

In November 1998, Thomas Henry Manning died after 57 years of membership in the Club. He was made an Honorary member of the Club in 1982. In August of this year, Michael Brandreth died. He had been member of the Council since 1998.

DAVE SMYTHE

Publications

The Publications Committee met three times in 1999.

Five issues of *The Canadian Field-Naturalist* were published: Volume 112, #4 and Volume 113, #1,2,3 and 4. These five issues contained: 962 pages; 59 articles; 45 notes; 1 COSEWIC article; 81 book reviews; 209 new titles; 1 commemorative tribute; 30 pages of News and Comment; and 2 indices comprising 67 pages. Volume 113, #1 was devoted entirely to a superlative history of the first 50 years of the Canadian Wildlife Service. There were no changes in the panel of Associate Editors.

Volume 33 of *Trail & Landscape* was published in four issues that contained 196 pages. For the first time in many years the majority of the articles did not deal with birds, but with flora and conservation, with 24% and 16% respectively of the total paging.

The Committee recommended that the OFNC provide some financial support towards the publication of *Lichens of North America*.

RONALD E. BEDFORD

The distribution of memberships in The Ottawa-Field-Naturalists' Club. (Does *not* include non-membership subscriptions to *The Canadian Field-Naturalist* – see Editor's report 114(2): 339).

CANADIAN			FOREIGN		Total
Type	Local	Other	USA	Other	
Family	360 (352)	23 (23)	2 (2)	2 (1)	387 (378)
Individual	344 (364)	125 (131)	23 (24)	3 (3)	495 (522)
Honorary	14 (14)	8 (9)	0 (0)	0 (0)	22 (23)
Life	17 (16)	21 (20)	5 (4)	1 (1)	44 (41)
Sustaining	8 (9)	1 (0)	0 (0)	0 (0)	9 (9)
Total	743 (755)	178 (183)	30 (30)	6 (5)	957 (973)

The Ottawa Field-Naturalists' Club Financial Statements for the year ended 30 September, 1999

Auditor's Report

To: The Members of THE OTTAWA FIELD-NATURALISTS' CLUB:

I have audited the balance sheet of THE OTTAWA FIELD NATURALISTS' CLUB as at September 30, 1999, the statement of changes in net assets, and the statements of operations. These financial statements are the responsibility of the organization's management. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, The Ottawa Field-Naturalists' Club derives some of its revenue from memberships, donations, and fund raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the organization.

In my opinion, except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenues referred to in the preceding paragraph, these financial statements present fairly, in all material respects, the financial position of the OFNC as at September 30, 1999, and the results of its operations and changes in net assets for the year then ended in accordance with generally accepted accounting principles.

JANET M. GEHR, C.A.
Chartered Accountant

North Gower, Ontario
February 7, 2000

The Ottawa Field-Naturalists' Club Balance Sheet

For the Year Ended September 30, 1999

	<u>1999</u>	<u>1998</u>
ASSETS		
CURRENT ASSETS		
Cash	\$ 17,344	\$ 10,035
Cash	\$ 28,378	\$ 17,344
Investment certificates	206,435	102,501
Marketable securities	79,568	75,776
Accounts receivable.....	9,287	10,933
Prepaid expenses.....	1,000	1,000
	<u>324,668</u>	<u>207,554</u>
Capital Assets	—	—
Land — Alfred Bog	3,348	3,348
	<u>\$ 328,016</u>	<u>\$ 210,902</u>
LIABILITIES AND FUND BALANCES		
CURRENT		
Accounts payable and accrued liabilities.....	\$ 14,000	\$ 13,996
Deferred revenue	13,800	11,303
	<u>27,800</u>	<u>25,299</u>
Life memberships.....	8,891	7,475
NET ASSETS		
Unrestricted	162,676	49,164
Club reserve	100,000	100,000
Seedathon.....	1,193	1,378
Anne Hanes memorial	870	870
de Kiriline-Lawrence	25,211	26,221
Macoun Baillie Birdathon	826	—
Alfred Bog	549	495
	<u>291,325</u>	<u>178,128</u>
	<u>\$ 328,016</u>	<u>\$ 210,902</u>

**The Ottawa Field Naturalists' Club Summary of Significant Accounting Policies
for the year ended 30 September, 1999**

The Ottawa Field-Naturalists' Club		
Statement of Operations		
For the Year Ended September 30, 1999		
	<u>1999</u>	<u>1998</u>
REVENUE		
Memberships	\$ 14,646	\$ 13,242
Trail and Landscape.....	226	233
Interest	1,725	1,670
GST rebate.....	1,132	—
Fletcher Wildlife Garden	1,245	—
Other	1,573	68
	<u>20,547</u>	<u>15,213</u>
OPERATING EXPENSES		
Affiliation fees	1,094	675
Computer	(66)	841
Membership	1,656	160
Office assistant	1,000	1,417
Telephone	1,202	1,250
Insurance.....	871	1,080
GST.....	1,710	1,455
Operations.....	925	3,887
	<u>8,392</u>	<u>10,765</u>
CLUB ACTIVITY EXPENSES		
Awards.....	165	411
Birds.....	400	269
Education and Publicity	217	144
Excursions and lectures	(160)	(541)
Macoun Field Club	783	1,101
Soiree	304	166
Trail and Landscape.....	7,788	7,260
Fletcher Wildlife Garden	—	825
Other	170	547
	<u>9,667</u>	<u>10,182</u>
	<u>18,059</u>	<u>20,947</u>
EXCESS REVENUE		
OVER EXPENSES	\$ 2,488	\$ (5,734)

The Canadian Field-Naturalist		
Statement of Operations		
For the Year Ended September 30, 1999		
	<u>1999</u>	<u>1998</u>
REVENUE		
Memberships	\$ 9,776	\$ 8,815
Subscriptions	30,734	24,210
Reprints.....	12,823	5,850
Publication charges.....	34,498	25,071
Interest and exchange	11,198	10,889
GST rebate	3,839	—
Other	3,595	—
	<u>106,463</u>	<u>74,835</u>
EXPENSES		
Publishing	58,707	58,765
Reprints.....	5,423	6,123
Circulation	12,048	5,134
Editing	4,541	2,852
Office Assistant	5,000	4,583
Honoraria	6,000	6,000
GST.....	6,348	4,897
Other	3,609	1,161
	<u>101,676</u>	<u>89,515</u>
EXCESS REVENUE OVER		
EXPENSES	<u>\$ 4,787</u>	<u>\$(14,680)</u>

The Ottawa Field-Naturalists' Club
Statement of Changes In Net Assets
For the Year Ended September 30, 1999¹

Net Assets	Beginning Balance	Excess Revenue CFN	Excess Revenue OFN	Donations Contributions	Expenses	1999 Ending Balance
Unrestricted	\$ 49,164	\$ 4,787	\$ 2,488	\$ 106,237	\$ -	\$ 162,676
Club Reserve	100,000	-	-	-	-	100,000
Seedathon	1,378	-	-	806	991	1,193
Anne Hanes Memorial	870	-	-	-	-	870
de Kirilin-Lawrence	26,221	-	-	1,818	2,828	25,211
Macoun Baillie Birdathon	-	-	-	826	-	826
Alfred Bog	495	-	-	54	-	549
	<u>\$ 178,128</u>	<u>\$ 4,787</u>	<u>\$ 2,488</u>	<u>\$ 109,741</u>	<u>\$ 3,819</u>	<u>\$ 291,325</u>

¹Note: A more detailed financial statement is available to any member who wishes to contact the Club.

A Review of the Status of Canada's Amphibian and Reptile Species: a Comparison of Three Ranking Systems

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We assigned national conservation priority ranks to the 93 native and introduced Canadian amphibian and reptile species using the International Union for the Conservation of Nature and Natural Resources (IUCN) [=World Conservation Union] criteria and The Association for Biodiversity Information (ABI) criteria independently. We used these results, along with national designations previously assigned to a number of these species by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), to compare the three ranking systems at the national scale. We also used existing IUCN and ABI ranks to compare these two systems at the global scale. At the global scale, considerable variability exists, and it is not possible to determine the rank under one system by determining the rank under the other — the only way to find out for certain is to evaluate the species against the criteria. At the national scale, there is not good correspondence between the COSEWIC system and the IUCN system. However, there is excellent correspondence between the COSEWIC and ABI systems: all 26 species with concern status assigned by COSEWIC (Endangered, Threatened, or Vulnerable) were ranked N1-N3, NX or NH using the ABI system. All five N4 and N5 species were ranked Not At Risk by COSEWIC. The ABI system appears to be more sensitive than the IUCN system at the lower risk levels, while the IUCN system focusses on the levels of higher risk. Species highly ranked using the ABI system (NX, NH, N1, or N2) always had a rank of concern using the IUCN system (RE, CR, EN, VU, or NT), whereas species ranked low in the ABI system (N4 or N5) were always ranked Least Concern (LC) using the IUCN system. We believe that this strong relationship will hold for other taxonomic groups. Both the IUCN and ABI ranking systems have merits, and it might be useful to evaluate species using both systems independently. We suggest combining the two ranks into a new national rank, and we present a simple way of doing this. This process should lead to a stronger justification for the status ultimately given. In the longer term, a single system incorporating the benefits of the ABI and IUCN systems is desirable. However, one drawback to making major changes to either system is that species already evaluated will have to be re-evaluated depending on the extent of the changes.

Key Words: International Union for the Conservation of Nature and Natural Resources (IUCN), [World Conservation Union], Association for Biodiversity Information (ABI), Conservation Data Centre (CDC), Committee on the Status of Endangered Wildlife in Canada (COSEWIC), endangered, threatened, vulnerable, special concern, Canada, rank, criteria, status, amphibian, reptile, designation.

As the world's biodiversity decreases (Biodiversity Convention Office 1995*), it becomes increasingly important to set priorities for its conservation. For certain taxonomic groups, enough is known for species to be handled on an individual basis, and for these groups a useful exercise is to rank each species according to degree of conservation concern. Indeed, numerous schemes for ranking species have been developed. However, there are two that are very widely used internationally. The system developed about three decades ago and updated in 1994 by the International Union for the Conservation of Nature and Natural Resources (IUCN) [now called the World Conservation Union but retaining the designation IUCN] is widely accepted throughout the world. The IUCN has ranked thousands of species (at the

global scale) according to their probability of extinction from the Earth. The results have been published as "IUCN Red Lists" (e.g., IUCN 1996, IUCN 1998). The IUCN has reviewed the global status of all the world's birds and mammals (IUCN 1996), but only some of the reptiles and amphibians (A. Brautigam, IUCN, personal communication). The other system, developed about 25 years ago by The Nature Conservancy (TNC), a U.S.-based international conservation agency, and the Association for Biodiversity Information (ABI) is widely used in the U.S., Canada, and a number of Latin American countries. ABI, and its associated Conservation Data Centres (CDCs) has ranked thousands of species at the global, national and sub-national (state or provincial) scales, including more than 30 000 North American taxa, encompassing vascular plant and vertebrate species (except marine fishes) at the global scale (L. Master, TNC, personal communication).

*See Documents Cited section.

For the past 22 years in Canada, species have been assessed for conservation concern by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (Shank 1999; Anonymous 1999). With Canada's signing of the Biodiversity Convention and subsequent preparation of its own Biodiversity Convention Strategy (Biodiversity Convention Office 1995*), the push for provincial and federal legislation to protect endangered species, and reaction from industry to address the issue (e.g., Alvo 1998*), have all heightened the interest within the conservation community to evaluate the status of Canadian species.

Amphibians and reptiles have long been a group with considerable conservation concern in Canada, due primarily to the fact that Canada is at the northern range limits for most species and many are rare within the country. They are also relatively well known distributionally in Canada (though the northern limits of many species have yet to be firmly established) with published national (Cook 1984) and provincial range maps (e.g. Hodge 1976; Preston 1982; Gilhen 1984; Green and Campbell 1984; Gregory and Campbell 1984; Weller and Oldham 1988; Russell and Bauer 1993; Bider and Matte 1994). Early efforts to identify amphibian and reptile species of conservation concern in Canada include publications by Cook (1964, 1970), Campbell (1969, 1977), Scott (1974*), and Gregory (1977).

Our purpose is to present the national rankings obtained using each of the three systems and to compare them in order to make recommendations for their use in Canada. We hope that this study will stimulate similar ranking exercises of species in other taxonomic groups and that such ranking efforts will be directed at all of the species in each taxonomic group (rather than just rare species), whenever possible, in order to provide a complete context of Canada's biodiversity.

Methods

We compiled data on the status of Canada's amphibians and reptiles from the existing literature, both national and international (Wright and Wright 1949; Cook 1984; Stebbins 1985; Chabot and St-Hilaire 1991; Conant and Collins 1991; Ernst et al. 1994; Weller and Green 1997; Petranksa 1998), regional studies and guides (Bleakney 1958; Cook 1966; Cook 1967; Logier 1958; Gorham 1970; Hodge 1976; Preston 1982; Maunder 1983; Nussbaum et al. 1983; Gilhen 1984; Green and Campbell 1984; Gregory and Campbell 1984; Strickland and Rutter 1986; Secoy 1987; Quinn 1991; Russell and Bauer 1993; Corkran and Thoms 1996; Elderkin and Boates 1996*; Powell and Russell 1996; Duncan 1997; Harding 1997; Gregory and Gregory *in press*; Oldham 1998a*), and provincial atlases (e.g., Weller and Oldham 1988; Bider and Matte

1991, 1994). Also useful were COSEWIC ranks (COSEWIC 2000*), national status reports (e.g., Cook 1981*; Oldham 1982*; Green 1986* [see also Green 1989]; Bogart and Licht 1991*; Bredin 1989*; Farr 1989*; Oldham and Campbell 1990*; Campbell et al. 1991*; Litzgus and Brooks 1996*; Alvo and Bonin 1999*), provincial status reports (e.g., Orchard 1991*; Wright 1998*), species recovery plans (e.g., Kellar et al. 1997; Prior et al. 1998), IUCN ranks and their documentation (IUCN 1996), global ranks assigned by ABI (GRANKs) along with their ranking documentation (TNC 1998*), provincial ranks (SRANKs) assigned by Canadian CDCs (which apply the ABI methodology at the provincial scale) along with their ranking documentation (e.g., Duncan 1997; Oldham 1997, 1998b), unpublished data (TNC 1998*) and technical and other reports (e.g., Beaulieu 1992; Bishop and Pettit 1992; Ducharme et al. 1992; Desrosiers 1995; Alberta Environmental Protection 1996; Haycock 1998*; Cannings et al. 1999). Information gaps were filled by personal communications — see Acknowledgments.

We then used this information to rank each species in Canada at the national scale by applying independently the ABI criteria and those of the IUCN. All of the data used to evaluate the ranking criteria for each species, as well as our reasoning for arriving at the ranks using both systems, are documented in electronic format using "Element National Ranking forms" designed by ABI. These forms allowed us to assign a letter rank (A-D) to each criterion using the ABI system (see below). In addition, they contained comment fields in which we could explain our choice of a letter rank and include additional information used in examining each criterion using the IUCN system. Two other forms were used to document information sources and nomenclature (scientific, English and French) and taxonomic comments (e.g., information on sub-species). These forms allowed the national ranks assigned using the ABI criteria (NRANKs) and their documentation to become incorporated, in electronic format, into the ABI Network, and thus made available to the Canadian CDCs, which now cover all Canadian provinces.

We did not attempt to rank any of the species using the COSEWIC system, but we present the existing designations assigned by COSEWIC as of the April 2000 meeting, and we note the species for which status reports are in progress. We present range ranks using the ABI system (e.g., N3N4), but treat them as the higher rank (e.g., N3) in the analyses for simplicity following ABI convention. Range ranks do not exist in the IUCN (e.g., CR/EN) or COSEWIC (e.g., T/V) systems. The three systems for ranking species are presented in detail below. Note that the criteria used in both the IUCN and ABI ranking systems are being reviewed and revised criteria will be adopted for use in both systems in 2000.

The IUCN Ranking System (adapted from the IUCN Web Site (<http://iucn.org>) and IUCN Species Survival Commission 1994)

IUCN ranks (at the global scale) are assigned by people or committees working within the IUCN network. Nations throughout the world are encouraged to apply the IUCN criteria at the national scale (Gardenfors 1996). Gardenfors et al. (1999) have recently produced draft guidelines for the application of IUCN criteria at national and regional levels. However, no program is in place for the IUCN to keep track of these ranking efforts or to make the national ranks available to other countries (M. Gimenez-Dixon, IUCN, personal communication).

IUCN Category Definitions:

RE (Regionally Extinct) – There is no reasonable doubt that the last individual potentially capable of reproduction within the region has died or disappeared from the region, or if a former visiting taxon, the last individual has died or disappeared from the region (Gardenfors et al. 1999).

EX (Extinct) – There is no reasonable doubt that the last individual has died. [N.B. The term "Threatened" is used to denote any species that is either CR, EN or VU, as defined below.]

CR (Critically Endangered) – Facing an extremely high risk of extinction in the wild in the immediate future as defined by the criteria.

EN (Endangered) – Not CR, but facing a very high risk of extinction in the wild in the near future as defined by the criteria.

VU (Vulnerable) – Not CR or EN, but facing a high risk of extinction in the wild in the medium-term future as defined by the criteria.

DD (Data Deficient) – There is inadequate information to make a direct or indirect assessment of its risk of extinction based on its distribution and/or population status.

LR (Lower Risk) – Has been evaluated and does not qualify for any of the Threatened categories (CR, EN, or VU), or DD. The three LR categories are CD, NT, and LC, as defined below.

CD (Conservation Dependent) – Does not qualify for VU only because of species-specific or habitat-specific conservation efforts, the cessation of which would result in the taxon qualifying for one of the threatened categories within a period of five years.

NT (Near Threatened) – Not CD, but almost qualifies for one of the VU criteria.

LC (Least Concern) – Not in any immediate danger of extirpation.

IUCN Criteria: These are the criteria by which a category (see above) is derived. In assessing species, it is recommended that all species assessed be evaluated against each criterion; however, the satisfaction of only one criterion is necessary to derive a category.

A = POPULATION REDUCTION – (1) observed, inferred, suspected or estimated reduction, or (2) projected or predicted reduction, of at least 20% (VU), or 50% (EN), or 80% (CR) in 10 years or 3 generations, whichever is longer, based on: (a) direct observation; (b) index of abundance appropriate for the taxon; (c) decline in areas of occupancy, extent of occurrence and/or quality of habitat; (d) actual or potential scales of exploitation, or (e) effects

of introduced taxa, hybridization, pathogens, pollutants, competitors, or parasites.

B = RESTRICTED DISTRIBUTION – extent of occurrence estimated to be less than 20000 km² (VU), or 5000 km² (EN) or 100 km² (CR), or area of occupancy estimated to be less than 2000 km² (VU), or 500 km² (EN), or 10 km² (CR), and any two of the three following: (1) severely fragmented, or known to exist in not more than 10 locations (VU), or five locations (EN), or a single location (CR); (2) continuing decline, observed, inferred, or projected in any one of: (a) extent of occurrence, (b) area of occupancy; (c) area, extent and/or quality of habitat; (d) number of locations or sub-populations; (e) number of mature individuals; and (3) extreme fluctuation in any one of: (a) extent of occurrence, (b) area of occupancy, (c) number of populations or sub-populations, (d) number of mature individuals.

C = POPULATION ESTIMATES – population estimated to number less than 10000 (VU), or 2500 (EN), or 250 (CR) mature individuals and either: (1) estimated, continuing decline of at least 10% in 10 years or three generations, whichever is longer (VU), or 20% in five years or two generations, whichever is longer (EN), or 25% in three years or one generation, whichever is longer (CR); or (2) continuing decline, observed, projected, inferred, number of mature individuals and population structure in the form of either (a) severely fragmented [no sub-population estimated to contain more than 1000 (VU), or 250 (EN), or 50 (CR) mature individuals]; or (b) all individuals are in a single sub-population.

D = RESTRICTED POPULATIONS – (1) population estimated to number less than 1000 (VU), or 250 (EN), or 50 (CR) mature individuals; or (2) population restricted in area of occupancy to less than 100 km² or less than five locations (VU).

E = PROBABILITY OF EXTINCTION – quantitative analysis showing the probability of extinction in the wild is at least 10% in 100 years (VU), or 20% in 20 years or five generations, whichever is longer (EN), or 50% in 10 years or three generations, whichever is longer (CR).

The ABI Ranking System (adapted in 1998 from the TNC Web Site: <http://www.tnc.org>)

As with the IUCN system, ABI ranks are assigned by people working within a network, in this case the ABI Network of CDCs, frequently with input from outside experts. The criteria are the same regardless of the scale at which they are being applied (Global, National, or Sub-national), but they are presented here for the national scale. Ranks always begin with a letter indicating the scale (G, N, or S), and can be presented at one, two or three scales (e.g., G5, G5S1 or G5N3S1).

For each species, six basic factors are considered, and a letter from A to D is assigned to each factor for which there is enough information. A species with all "A"s will likely be ranked N1, whereas a species with all "D"s will likely receive an N4 or N5. However, the person doing the ranking must exercise judgement in determining whether more weight should be given to certain factors, particularly when there is a high degree of variability among letter values. They also must weigh the importance of other

factors, and closely consider the textual information accompanying the letter values. Thus the letters serve only as general guides. The six basic ABI ranking factors are:

1. The estimated number of Element Occurrences (EOs) (= populations) in the nation: A = 0 - 5; B = 6 - 20; C = 21 - 100; D = 101+.
2. The estimated national abundance (measured by number of individuals, area, or stream length): A = fewer than 1000 individuals, fewer than 800 ha, or fewer than 16 km of stream length; B = 1000 - 3000 individuals, 800 - 4000 ha, or 16 - 80 km; C = 3000 - 10 000 individuals, 4000 - 20 000 ha, or 80 - 400 km; D = over 10 000 individuals, over 20 000 ha, or over 400 km.
3. The estimated extent of the national range: A = very small range, less than 3% of nation's territory; B = narrow range, less than 10% of nation's territory; C = moderately widespread, less than half of nation's territory; D = widespread, more than half of nation's territory.
4. The short- and long-term trends in population size, area of occupancy, extent of range, and/or number of populations over the national range: A = declining rapidly; B = declining; C = stable; D = increasing.
5. The estimated number of adequately protected EOs throughout the nation: A = believed to be none protected; B = at least one protected EO; C = several protected EOs; D = many protected EOs; U = unknown whether any protected.
6. The degree to which it is threatened in the nation: A = very threatened in the nation, species or community directly exploited or threatened by natural or man-made forces; B = moderately threatened in the nation, habitat or community lends itself to alternate use; C = not very threatened in the nation, self-protecting by unsuitability for other uses; D = unthreatened in the nation, although a minor proportion of occurrences might be threatened.

ABI Rank Definitions:

N# = Numeric rank - A numeric rank (N1 through N5) of relative endangerment based primarily on the number of occurrences within the nation. (Note: Other factors, such as a low reproductive rate, population trend, threats, etc., in addition to number of occurrences, are considered when assigning a rank, so the numbers of occurrences suggested for each numeric rank below are guidelines.)

N1 = Critically imperiled in the nation because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the nation. Typically five or fewer occurrences or very few remaining individuals.

N2 = Imperiled in the nation because of rarity or because of some factor(s) making it very vulnerable to extirpation from the nation. Typically 6 to 20 occurrences or few remaining individuals.

N3 = Vulnerable in the nation. Typically 21 to 100 occurrences.

N4 = Widespread, abundant, and apparently secure in nation, with many occurrences, but of possible long-term concern. Often on the order of 100 to 1000 occurrences.

N5 = Demonstrably widespread, abundant, and secure in the nation, and essentially ineradicable under present conditions. Often much more than 1000 occurrences.

N#N# = Numeric range rank - A range between two of the numeric ranks. Denotes range of uncertainty about the

exact rank. Ranges cannot skip more than one rank (e.g., N1N4 is not allowed).

N? = Unranked - Not yet ranked in the nation.

NU = Unrankable - Possibly in peril in the nation, but status uncertain; need more information.

NE = Exotic - An exotic established in the nation; may be native in nearby regions.

NE# = Exotic numeric - An exotic established in the nation that is assigned a number rank of NE1 to NE5.

NA = Accidental - accidental or casual in the nation (i.e., infrequent and outside usual range).

NZ = Zero occurrences - Not of practical conservation concern in the nation, because there are no definable places where the taxon is found on a regular basis, although it is native and appears regularly in the nation.

NP = Potential - potentially occurring in the nation but no occurrences reported.

NR = Reported - reported in the nation but without persuasive documentation that would provide a basis for either accepting or rejecting (e.g., misidentified specimen) the report.

NRF = Reported falsely - erroneously reported in the nation and the error has persisted in the literature.

NH = Historical - occurred historically in the nation (with the expectation that it may be rediscovered), perhaps having not been verified in the past 20 years, and suspected to still be extant.

NX = Extirpated - believed to be extirpated from the nation. (N.B. GX = Extinct)

The COSEWIC Ranking System (from COSEWIC 2000)*

COSEWIC Definitions [Authors' note: We have adopted 1-letter codes for most COSEWIC categories, which are distinct from the 2-letter codes used by the IUCN and the alphanumeric codes used by ABI]:

Extinct - No longer exists. (No Canadian amphibian or reptile species are extinct.)

X (Extirpated) - No longer existing in the wild in Canada, but occurring elsewhere (e.g., in captivity or in the wild in the U.S.).

E (Endangered) - Facing imminent extirpation or extinction.

T (Threatened) - Likely to become endangered if limiting factors are not reversed.

S (Special Concern) - Of special concern because of characteristics that make it particularly sensitive to human activities or natural events. [Formerly described as "Vulnerable" from 1990 to 1999 or "Rare" prior to 1990.]

N (Not At Risk) - Evaluated and found to be not at risk.

D (Data Deficient) - There is insufficient scientific information to support status designation. [Formerly "Indeterminate".]

Taxonomy

Table 1 presents the names and conservation status ranks for each of the 93 Canadian amphibian and reptile species (48 reptiles and 45 amphibians). We are using a conservative taxonomic treatment, following the nomenclature used by ABI, in order to be consistent with the names used in most North American field guides (e.g., Cook 1984; Stebbins

1985; Conant and Collins 1991) and Canadian regional works. Scientific and English common names for native and non-accidental species used in Table 1 follow the ABI (1999) (see <http://consci.tnc.org/src/docs/caaa.htm> for amphibians and <http://consci.tnc.org/src/docs/caar.htm> for reptiles); names for introduced and accidental species largely follow Cook (1984). The nomenclature followed by ABI is based on Society for the Study of Amphibians and Reptiles 1971 *et seq.*; King and Burke 1989; Iverson 1992; Ernst et al. 1994; and Collins 1997 for reptiles and Society for the Study of Amphibians and Reptiles 1971 *et seq.*; Frost 1985; Duellman 1993; Collins 1997; and Petranks 1998 for amphibians (see <http://consci.tnc.org/src/source99.htm>). Species are ordered alphabetically by scientific name within each Order. French common names follow, in order of declining priority, Desrosiers (1995); Cook (1984); Bider and Matte (1994); Weller and Green (1997); Bider and Matte (1991); and Ouellet and Cook (1981). Some species not known from Quebec (e.g., *Sonora semiannulata*) do not appear to have French common names. The recent proposed splitting of several widespread species (e.g., *Ambystoma tigrinum*, *Pseudacris triseriata*, *Coluber constrictor*) has not been universally accepted by the North American herpetological community. Following a more "splitting" taxonomic approach (e.g., that recommended by Collins 1991, 1997) would result in three additional Canadian species: *Ambystoma mavortium* (for the western Canadian *A. tigrinum* populations), *Pseudacris maculata* (for boreal and prairie [James Bay to British Columbia] populations of *P. triseriata*), and *Coluber mormon* (for the western *C. constrictor* subspecies).

We have not evaluated subspecies in this analysis. Some CDCs rank and track subspecies while others do not. There are some widely accepted subspecies in Canada that are of both global and national conservation concern. For example, the Lake Erie Water Snake (*Nerodia sipedon insularum*), restricted to islands in western Lake Erie (in Ontario and Ohio), is ranked G5T2 (the "T" rank applies to the subspecies) and would be ranked N2 in Canada. COSEWIC has given an Endangered status to the Lake Erie Water Snake in Canada. Another subspecies of global and national conservation significance is the Eastern Massasauga (*Sistrurus catenatus catenatus*), globally ranked G3G4T3. Even at the species level, the taxonomy of some Canadian amphibians and reptiles is not agreed on. Some recent authors (e.g., Collins 1997; Harding 1997) recognize the Eastern Fox Snake (*Elaphe gloydi*) as a distinct species, while others (e.g., Cook 1984; Conant and Collins 1991) treat it as a subspecies, *Elaphe vulpina gloydi*. Additional taxonomic notes on Canadian species can be found as footnotes to Table 1.

Conservation Status

The IUCN ranks species at the global level (IUCN 1996). GRANKs for all Canadian amphibian and reptile species were provided in 1998 by ABI's Zoology Department in Boston. We developed ranks at the national scale using the IUCN criteria and the ABI criteria independently. COSEWIC designations were obtained from COSEWIC (1999), while lists of species for which status reports were in progress were provided by the two COSEWIC Reptiles and Amphibians Sub-Committee Chairs (D. M. Green and R. J. Brooks, COSEWIC, personal communications). Provincial SRANKs were provided by the CDC zoologists for the 10 Canadian provinces or taken from published sources (e.g., Duncan 1997; Oldham 1997, 1998a*) or data centre web pages (see <http://www.abi-canada.ca/english/about.htm>).

Results

Global Scale (IUCN and ABI systems)

The number of species with ranks indicating some concern at the global level (as we interpret the two sets of rank definitions) are similar under the two ranking systems (Table 2). Using the IUCN system, 12% (11 of 93) of Canadian species are Threatened (8), Near Threatened (3), Conservation Dependent (0), or Data Deficient (0), while under the ABI system, 9% (8 of 93) of the species are ranked G1-G3. Of the 11 species with IUCN ranks of concern at the global level, three (27%) are ranked G5 by the Heritage Network, suggesting that there is not always very good correspondence between the two systems. Only one species is ranked Critically Endangered (CR) and only one species is ranked G1 (the Atlantic Ridley in both cases). That the only species ranked CR was ranked G1, and vice versa, suggests that there could be good correspondence at these high levels of concern. No species are ranked G2. The only G2G3 species (Oregon Spotted Frog) was not designated by the IUCN (having been recently split from the Columbia Spotted Frog), so it is difficult to comment on the correspondence between the two systems at that level. The four species that were ranked G3 and that had IUCN ranks were ranked either EN or VU, while the three species that were ranked G4 and that had IUCN ranks were ranked EN, VU or NT. Finally, the three G5 species with IUCN designations were either VU or NT. Conversely, the four EN species were either G3 or G4, while the three VU species with GRANKs were G3, G4 or G5, and the three NT species were G4 or G5. These correspondences are summarized in Table 3. Clearly, as the rank increases using one system, it tends to increase using the other system. However, considerable variability exists, and it is not possible to determine the rank under one system by merely having determined the rank under the other – the only way to find out for certain is to evaluate the species against the criteria.

TABLE 1. Conservation status of Canada's amphibian and reptile species at the global, national and provincial scales according to three ranking systems.

Scientific Name	English Name	French Name	Global		National (Canada)					Provincial Ranks Assigned by CDCs ¹										NF, LAB ²
			IUCN	ABI	IUCN	ABI	COS	BC	AB	SK	MB	ON	QC	NB	PEI	NS				
AMPHIBIANS																				
Salamanders																				
<i>Ambystoma gracile</i>	Northwestern Salamander	Salamandre foncée	—	G5	LC	N4N5	N	S4S5	—	—	—	—	—	—	—	—	—	—	—	
<i>Ambystoma Jeffersonianum</i> ³	Jefferson Salamander	Salamandre de Jefferson	—	G5	NT(B)	N2	*4	—	—	—	S2	—	—	—	—	—	—	—	—	
<i>Ambystoma laterale</i> ³	Blue-spotted Salamander	Salamandre à points bleus	—	G5	LC	N5	—	—	—	S3S4	S4	S5	S4	S4	S5	—	S4	—	—	
<i>Ambystoma macrodactylum</i>	Long-toed Salamander	Salamandre à longs doigts	—	G5	LC	N5	—	—	—	—	S4	S5	S5	S5	S5	—	—	—	—	
<i>Ambystoma maculatum</i>	Spotted Salamander	Salamandre maculée	—	G5	LC	N5	—	—	—	—	S4	S5	S5	S5	S5	—	—	—	—	
<i>Ambystoma texanum</i>	Smallmouth Salamander	Salamandre à nez court	—	G5	VU(D2)	N1	S	—	—	—	S1	—	—	—	—	—	—	—	—	
<i>Ambystoma tigrinum</i> ⁵	Tiger Salamander	Salamandre tigrée	—	G5	LC	N5	*	S2	S4	S5	S4S5	SX	—	—	—	—	—	—	—	
<i>Aneides ferreus</i> ⁶	Clouded Salamander	Salamandre pommelée	—	G4	LC	N4	*	S4	—	—	—	—	—	—	—	—	—	—	—	
<i>Desmognathus fuscus</i>	Dusky Salamander	Salamandre sombre du nord	—	G5	LC	N3N4	N	—	—	—	S1	S3	S3	—	—	—	—	—	—	
<i>Desmognathus ochrophaeus</i>	Mountain Dusky Salamander	Salamandre sombre des montagnes	—	G5	VU(D2)	N2	S	—	—	—	—	S2	—	—	—	—	—	—	—	
<i>Dicamptodon tenebrosus</i>	Pacific Giant Salamander	Grande salamandre	—	G5	EN(C2b)	N2	S ^{8,7}	S2	—	—	—	—	—	—	—	—	—	—	—	
<i>Ensatina eschscholtzii</i>	Ensatina	Salamandre variable	—	G5	LC	N4	N	S4	—	—	—	—	—	—	—	—	—	—	—	
<i>Eurycea bislineata</i>	Northern Two-lined Salamander	Salamandre à deux lignes	—	G5	LC	N5	—	—	—	—	S4	S4	S5	—	—	—	—	S5	—	
<i>Gyrinophilus porphyriticus</i>	Spring Salamander	Salamandre pourpre	—	G5	NT(B,D1,2)	N2	S	—	—	—	SX	S2	—	—	—	—	—	—	—	
<i>Hemidactylium scutatum</i>	Four-toed Salamander	Salamandre à quatre doigts	—	G5	LC	N4	N	—	—	—	S4	S3	S1	—	S3S4	—	—	—	—	
<i>Necturus maculosus</i>	Mudpuppy	Necture tacheté	—	G5	LC	N4	N	—	—	—	S4	—	S4	—	—	—	—	—	—	
<i>Notophthalmus viridescens</i>	Eastern Newt	Triton vert	—	G5	LC	N5	—	—	—	—	S5	S5	S5	S5	S5	—	—	—	—	
<i>Plethodon cinereus</i>	Redback Salamander	Salamandre rayée	—	G5	LC	N5	—	—	—	—	S5	S5	S5	S4	S5	—	—	—	—	
<i>Plethodon idahoensis</i> ⁸	Coeur d'Alene Salamander	Salamandre de Coeur d'Alène	—	G3	EN(D1)	N2	S	S2	—	—	—	—	—	—	—	—	—	—	—	
<i>Plethodon vehiculum</i>	Western Redback Salamander	Salamandre à dos rayé	—	G5	LC	N4	*	S4	—	—	—	—	—	—	—	—	—	—	—	
<i>Pseudotriton ruber</i> ⁹	Red Salamander	Salamandre rousse	—	G5	—	NEX	—	—	—	—	SEX	—	—	—	—	—	—	—	—	
<i>Taricha granulosa</i>	Roughskin Newt	Triton rugueux	—	G5	LC	N4N5	—	S4S5	—	—	—	—	—	—	—	—	—	—	—	
Frogs and Toads																				
<i>Acris crepitans</i>	Northern Cricket Frog	Rainette grillon	—	G5	RE	NH	E*	—	—	—	SH	—	—	—	—	—	—	—	—	
<i>Asaphus truei</i>	Tailed Frog	Grenouille-à-queue	—	G4	LC	N3N4	E ¹⁰	S3S4 ¹⁰	SRF	—	—	—	—	—	—	—	—	—	—	
<i>Bufo americanus</i>	American Toad	Crapaud d'Amérique	—	G5	LC	N5	—	—	—	—	S5	S5	S5	S5	S5	S5	S5	SE	S5	

(Continued)

TABLE 1. (Continued)

Scientific Name	English Name	French Name	Global		National (Canada)				Provincial Ranks Assigned by CDCs ¹							NF, LAB ²	
			IUCN	ABI	IUCN	ABI	COS	BC	AB	SK	MB	ON	QC	NB	PEI		NS
Frogs and Toads (concluded)																	
<i>Bufo boreas</i>	Western Toad	Crapaud de l'Ouest	EN	G4	LC	N4	*	S4	S4	—	—	—	—	—	—	—	—
<i>Bufo cognatus</i>	Great Plains Toad	Crapaud des steppes	—	G5	LC	N3	S	—	S2	S3	\$2,S3	—	—	—	—	—	—
<i>Bufo fowleri</i> ¹¹	Fowler's Toad	Crapaud de Fowler	—	G5	EN(B1,3d)	N2	T	—	—	—	—	S2	—	—	—	—	—
<i>Bufo hemiophrys</i> ¹²	Canadian Toad	Crapaud du Canada	—	G4	LC	N4	*	—	S4	S4	S4	—	—	—	—	—	—
<i>Hyla chrysoscelis</i>	Cope's Gray Treefrog	Rainette criarde	—	G5	LC	N4	N	—	—	—	S4	SR	—	—	—	—	—
<i>Hyla versicolor</i>	Gray Treefrog	Rainette versicolore	—	G5	LC	N5	—	—	S4	S5	S4	S5	S4	S3	—	—	—
<i>Pseudacris crucifer</i> ¹³	Spring Peeper	Rainette crucifère	—	G5	LC	N5	—	—	S4	S5	S5	S5	S5	S5	S5	—	—
<i>Pseudacris regilla</i> ¹⁴	Pacific Chorus Frog	Rainette du Pacifique	—	G5	LC	N5	*	S5	—	—	—	—	—	—	—	—	—
<i>Pseudacris triseriata</i> ¹⁵	Western Chorus Frog	Rainette faux-grillon	—	G5	LC	N5	S	S3S4	S5	S5	—	—	S3	—	—	—	—
<i>Rana aurora</i>	Red-legged Frog	Grenouilles à pattes rouges	—	G4	LC	N3N4	S	—	—	—	—	—	S4	S5	—	S5	—
<i>Rana catesbeiana</i>	Bullfrog	Ououaron	—	G5	LC	N5	SE	SE	—	—	S2	S5	S5	S5	\$4S5	S5	SE, —
<i>Rana clamitans</i>	Green Frog	Grenouille verte	—	G5	LC	N5	SE	SE	—	—	—	—	—	—	—	—	—
<i>Rana luteiventris</i> ¹⁶	Columbia Spotted Frog	Grenouille maculée de la Colombie	—	G4	LC	N4	N	S4	S3	—	—	—	—	—	—	—	—
<i>Rana palustris</i>	Pickrel Frog	Grenouille des marais	—	G5	LC	N5	N	—	—	—	—	S4	S3	S5	—	S5	—
<i>Rana pipiens</i>	Northern Leopard Frog	Grenouille léopard	—	G5	LC	N5	E,S,N ¹⁷	S1	\$2S3	S3	S4	S5	S5	S5	\$4S5	S5	—, \$2S3
<i>Rana pretiosa</i>	Oregon Spotted Frog	Grenouille maculée de l'Oregon	—	G2,G3	CR(B1,2)	N1	*	S1	—	—	—	—	—	—	—	—	—
<i>Rana septentrionalis</i>	Mink Frog	Grenouille du nord	—	G5	LC	N5	—	—	—	—	S3	S5	S5	S5	—	S5	—,S5
<i>Rana sylvatica</i>	Wood Frog	Grenouille des bois	—	G5	LC	N5	—	S5	S5	S4	S5	S5	S5	S5	S5	S5	SE,S5
<i>Spea bombifrons</i> ¹⁸	Plains Spadefoot	Crapaud des Plaines	—	G5	NT(B)	N3N4	S	—	S3	S3	S3S4	—	—	—	—	—	—
<i>Spea intermontana</i> ¹⁸	Great Basin Spadefoot	Crapaud du Grand Bassin	—	G5	LC	N3	S	S3	—	—	—	—	—	—	—	—	—
REPTILES																	
Turtles ¹⁹																	
<i>Apalone spinifer</i> ²⁰	Spiny Softshell	Tortue-molle à épines	—	G5	VU(C2a,D1)	N2	T	—	—	—	S3	S1	—	—	—	—	—
<i>Caretta caretta</i>	Loggerhead	Caouane	EN	G3	—	NA	—	—	—	—	—	—	SA	—	—	SA	—
<i>Chelonia mydas</i>	Green Turtle	Tortue verte	EN	G3	—	NA	—	SA	—	—	—	—	—	—	—	—	—
<i>Chelydra serpentina</i>	Common Snapping Turtle	Chelydre serpentine	—	G5	LC	N5	—	SE	SE	S3	S3	S5	S4	S4	—	S5	—
<i>Chrysemys picta</i>	Painted Turtle	Tortue peinte	—	G5	LC	N5	—	\$3S4	S1	S4	S4	S5	S5	S5	—	S5	—
<i>Clemmys guttata</i>	Spotted Turtle	Tortue ponctuée	VU	G5	NT(C2a)	N3	S	—	—	—	S3	S1	—	—	—	—	—
<i>Clemmys insculpta</i>	Wood Turtle	Tortue des bois	VU	G4	LC	N3	S	—	—	—	—	S2	S2	S3	—	S3	—
<i>Clemmys marmorata</i> ²¹	Western Pond Turtle	Tortue de l'Ouest	VU	G3	RE	NX	*	SX	—	—	—	—	—	—	—	—	—
<i>Demochelys coriacea</i>	Leatherback	Tortue luth	EN	G3	EN (A1a,b,d)	NIN2	E*	SIS2N	—	—	—	—	SZN	SIS2N	—	SIS2N	—
<i>Emydoidea blandingii</i>	Blanding's Turtle	Tortue mouchetée	NT	G4	LC	N4	T* ²²	—	—	—	—	S4	S2	—	—	S1	—
<i>Graptemys geographica</i>	Common Map Turtle	Tortue géographique	—	G5	LC	N4	*	—	—	—	—	S4	S1	—	—	—	—
<i>Lepidochelys kempi</i>	Atlantic Ridley	Tortue batarde	CR	G1	—	NA	—	—	—	—	—	—	—	—	—	SA	—, SA, —
<i>Sternotherus odoratus</i>	Common Musk Turtle	Tortue musquée	—	G5	LC	N4	*	—	—	—	—	S4	S1	—	—	—	—
<i>Terrapene carolina</i> ²³	Eastern Box Turtle	Tortue tabatière	NT	G5	—	NE	*	—	—	—	—	SE1	SE	—	—	—	—
<i>Trachemys scripta</i>	Slider	Tortue à oreilles rouges	NT	G5	—	NE	—	—	—	—	—	SE1	SE	—	—	—	—

Continued

(Continued)

TABLE 1. (Continued)

Scientific Name	English Name	French Name	Global		National (Canada)							Provincial Ranks Assigned by CDCs ¹							NF, LAB ²
			IUCN	ABI	IUCN	ABI	COS	BC	AB	SK	MB	ON	QC	NB	PEI	NS			
Lizards (concluded)																			
<i>Elgaria coerulea</i>	Northern Alligator Lizard	Lézard-alligator boréale	—	G5	LC	N4N5	*	S4S5	—	—	—	—	—	—	—	—	—	—	
<i>Eumeces fasciatus</i>	Five-lined Skink	Scinque pentalgè	—	G5	LC	N3	S	—	—	—	S3	—	—	—	—	—	—	—	
<i>Eumeces septentrionalis</i>	Northern Prairie Skink	Scinque des Prairies	—	G5	NT(D2)	N2	S	—	—	S2	—	—	—	—	—	—	—	—	
<i>Eumeces skiltonianus</i>	Western Skink	Scinque de l'Ouest	—	G5	LC	N4	LC	S4	—	—	—	—	—	—	—	—	—	—	
<i>Phrynosoma douglasii</i> ²⁴	Short-horned Lizard	Iguane à petites cornes	—	G5	RE	NH	X	SH	—	—	—	—	—	—	—	—	—	—	
<i>Phrynosoma hernandesi</i> ²⁴	Pygmy Short-horned Lizard	Iguane à petites cornes	—	G5	NT(B1,2)	N2N3	S	—	S2	S2S3	—	—	—	—	—	—	—	—	
<i>Podarcis muralis</i> ²⁵	Common Wall Lizard	Lézard des murailles	—	G?	—	NE	—	SE	—	—	—	—	—	—	—	—	—	—	
Snakes																			
<i>Charina bottae</i>	Rubber Boa	Boa caoutchouc	—	G5	LC	N3N4	*	S3S4	SR	—	—	—	—	—	—	—	—	—	
<i>Coluber constrictor</i> ²⁶	Racer	Couleuvre agile	—	G5	LC	N4	E,S,N ²⁷	S3S4	S3	—	—	S1	—	—	—	—	—	—	
<i>Contia tenuis</i>	Sharptail Snake	Couleuvre à queue fine	—	G5	VU(D1)	N1	E	S1	—	—	—	—	—	—	—	—	—	—	
<i>Crotalus horridus</i>	Timber Rattlesnake	Crotale des bois	—	G4	RE	NX	*	—	—	—	SX	SR	—	—	—	—	—	—	
<i>Crotalus viridis</i>	Western Rattlesnake	Crotale de l'Ouest	—	G5	LC	N3N4	*	S3	S3	—	—	—	—	—	—	—	—	—	
<i>Diadophis punctatus</i>	Ringneck Snake	Couleuvre à collier	—	G5	LC	N5	—	—	—	—	S4	S3	S4	—	S5	—	—	—	
<i>Elaeophis obsoleta</i>	Eastern Rat Snake	Couleuvre obscure	—	G5	LC	N3	T	—	—	—	—	S3	—	—	—	—	—	—	
<i>Elaeophis vulpinus</i> ²⁸	Fox Snake	Couleuvre fauve	—	G5	NT(C)	N3	T	—	—	—	S3	—	—	—	—	—	—	—	
<i>Heterodon nasicus</i>	Western Hognose Snake	Couleuvre à nez retroussé	—	G5	NT(B)	N3	*	—	S2	S3	S2	—	—	—	—	—	—	—	
<i>Heterodon platirhinos</i>	Eastern Hognose Snake	Couleuvre à nez plat	—	G5	LC	N3	S	—	—	—	S3	—	—	—	—	—	—	—	
<i>Hypsiglena torquata</i>	Night Snake	Couleuvre nocturne	—	G5	VU(B1,2)	N1	*	S1	—	—	—	—	—	—	—	—	—	—	
<i>Lampropeltis triangulum</i>	Milk Snake	Couleuvre tachetée	—	G5	LC	N5	*	—	—	—	S3	S3	—	—	—	—	—	—	
<i>Lioclorophis vernalis</i> ²⁹	Smooth Green Snake	Couleuvre verte	—	G5	LC	N5	—	—	—	—	S3S4	S4	S4	S5	S3	S5	—	—	
<i>Nerodia sipedon</i>	Northern Water Snake	Couleuvre d'eau	—	G5	LC	N5	E ³⁰	—	—	—	—	S5	S3	—	—	—	—	—	
<i>Pituophis catenifer</i> ³¹	Gopher Snake	Couleuvre à nez mince	—	G5	LC	N3	*	S3	S3	—	—	—	—	—	—	—	—	—	
<i>Regina septemvittata</i>	Queen Snake	Couleuvre royale	—	G5	VU(C2a)	N2	T	—	—	—	S2	—	—	—	—	—	—	—	
<i>Sistrurus catenatus</i>	Massasauga	Massasauga	—	G3G4	LC	N3	T	—	—	—	S3	—	—	—	—	—	—	—	
<i>Sonora semiannulata</i> ³²	Ground Snake	—	—	G5	—	NRF	—	SRF	—	—	—	—	—	—	—	—	—	—	
<i>Soreria dekayi</i>	Brown Snake	Couleuvre brune	—	G5	LC	N5	*	—	—	—	S5	S2	—	—	—	—	—	—	
<i>Soreria occipitomaculata</i>	Redbelly Snake	Couleuvre à ventre rouge	—	G5	LC	N5	—	—	—	S3	S4	S5	S5	S5	S4S5	S5	—	—	
<i>Thamnophis butleri</i>	Butler's Garter Snake	Couleuvre à petite tête	—	G4	NT(B1,2)	N2	S	—	—	—	S2	—	—	—	—	—	—	—	
<i>Thamnophis elegans</i>	Western Terrestrial	Couleuvre de l'Ouest	—	G5	LC	N5	—	S5	S3S4	S4	—	—	—	—	—	—	—	—	
<i>Thamnophis ordinoides</i>	Garter Snake	Couleuvre du Nord-Ouest	—	G5	LC	N4	*	S4	—	—	—	—	—	—	—	—	—	—	
<i>Thamnophis radix</i>	Plains Garter Snake	Couleuvre des Plaines	—	G5	LC	N5	—	S4	S5	S4	—	—	—	—	—	—	—	—	
<i>Thamnophis sauritus</i>	Eastern Ribbon Snake	Couleuvre mince	—	G5	LC	N4	*	—	—	—	S4	—	—	—	—	S2S3	—	—	
<i>Thamnophis sirtalis</i>	Common Garter Snake	Couleuvre rayée	—	G5	LC	N5	—	S5	S3	S5	S3S4	S5	S5	S5	S5	S5	S5	—	

¹No columns are provided for the three Canadian territories of Yukon, Northwest Territories and Nunavut, since no Conservation Data Centres currently cover these jurisdictions. However the presence and status of amphibians and reptiles in these territories was taken into account when assigning national IUCN and ABI ranks. Occurrence of amphibians and reptiles in Canadian territories is as follows: Yukon – *Bufo boreas*, *Rana luteiventris*, *Rana sylvatica*; Northwest Territories – *Bufo americanus*, *Bufo hemiophrys*, *Pseudacris triseriata*, *Rana pipiens*, *Rana sylvatica*, *Thamnophis sirtalis*; Nunavut – *Rana sylvatica* (based on Hodge 1976; Cook 1984; Fournier 1997; Weller and Green 1997).

(Footnotes continued)

- ²Administered by the same government, insular Newfoundland (NF) and Labrador (LAB) are very different biogeographically and species occurring there are assigned different ranks by the Atlantic Canada CDC (K. Bredin personal communication) and government of Newfoundland (J. Brazil personal communication). We treat them in the same column, with "—, S44" indicating the species is present in neither and "—, S44" indicating absent in NF and S4 in LAB.
- ³*Ambystoma jeffersonianum* and *A. laterale* have hybridized extensively in Ontario and some authors have accorded species status (as *A. tremblayi* and *A. platineum*) to these largely triploid hybrids (see Lowcock et al. 1987; Petraska 1998).
- ⁴* = COSEWIC status report or status update report in preparation or in review (D. M. Green and R. J. Brooks, personal communication).
- ⁵*Ambystoma tigrinum* is a taxonomically complex species with three Canadian subspecies (Cook 1984). Recent molecular studies (e.g., Shaffer and McKnight 1996) have suggested that there are more than one species in the *A. tigrinum* complex, and Collins (1997) includes the western subspecies (*diaboli* and *melanostictum*) in *A. mavortium* (occurring in B.C., Alberta, Saskatchewan, and Manitoba). The Eastern Tiger Salamander (*A. t. tigrinum*) occurs in Manitoba (S2) and Ontario (SX).
- ⁶Jackson (1998) has presented evidence that British Columbia Clouded Salamanders were introduced from California and that these salamanders are a different species from the Clouded Salamanders of Oregon. The name Wandering Salamander, *Aneides vagrans*, is proposed for the Clouded Salamanders of British Columbia and California.
- ⁷Species with an existing COSEWIC designation and a report in preparation (e.g., EN*) actually have a status update report in preparation. In these cases we used the current designation (e.g., EN) in the analyses.
- ⁸Included by some authors (e.g., Smith 1978; Nussbaum et al. 1983) as a subspecies of Van Dyke's Salamander (*P. varadykei idahoensis*).
- ⁹The sole Canadian record of *Pseudotriton ruber* is thought to have been accidental introduction through transport of live bait by fishermen (Cook 1984).
- ¹⁰The coastal and Kootenay "populations" of Tailed Frog are quite distinctive genetically and could be considered separate subspecies, or even separate species. The British Columbia CDC has ranked the coastal population S3S4 and the Kootenay population S1 (Cannings et al. 1999). COSEWIC (2000*) has designated the Pacific coast population as Special Concern and the southern mountain (Kootenay) population as Endangered.
- ¹¹Often considered a subspecies of Woodhouse's Toad, *Bufo woodhousei fowleri* (e.g., Cook 1984), following Meacham (1962).
- ¹²Considered a subspecies of the American Toad, *Bufo americanus hemiophys*, by some authors (e.g., Cook 1983).
- ¹³Until recently placed in the genus *Hyla* (e.g., Cook 1984).
- ¹⁴Retained in the genus *Hyla* (as *H. regilla*, Pacific Tree Frog) by some authors (e.g., Collins 1997).
- ¹⁵Some authors (e.g., Collins 1997) consider the Boreal Chorus Frog (*Pseudacris triseriata maculata*) to be a separate species, *Pseudacris maculata*, based on the findings of Platz (1989).
- ¹⁶The Columbia Spotted Frog (*Rana lateralis*) was recently split from the Oregon Spotted Frog (*Rana pretiosa*) based on morphometric and allozyme data (Green et al. 1996, 1997).
- ¹⁷The Northern Leopard Frog is ranked by COSEWIC as Endangered in British Columbia, and Special Concern in Prairie Canada (Alberta, Saskatchewan, Manitoba), but Not at Risk in eastern Canada.
- ¹⁸Some authors (e.g., Leonard et al. 1993) retain the genus *Scaphiopus* instead of *Spea*.
- ¹⁹The Pacific Ridley (*Lepidochelys olivacea*), which has occurred in the Pacific Ocean off Oregon (Ernst et al. 1994), Washington (Storm and Leonard 1995), and the Alaska panhandle (Iverson 1992), has almost certainly passed through British Columbia coastal waters, though it has not been reported from Canada.
- ²⁰Retained in the genus *Trionyx* by some authors (e.g., Ernst et al. 1994).
- ²¹Several authors (e.g., Cook 1984; Gregory and Campbell 1984) suggest that *Clammys marmorata* may not be native to Canada.
- ²²Nova Scotia populations of the Blanding's Turtle are designated Threatened by COSEWIC: a status report in preparation will consider the entire Canadian range.
- ²³The native or introduced status of Eastern Box Turtle (*Terrapene carolina*) is difficult to determine, however, most recent authors have considered it non-native (e.g., Cook 1984; Harding 1997; Oldham 1998b).
- ²⁴Based on the mtDNA studies of Zamudio et al. (1997) most recent authors consider Canada's two *Phrynosoma* to be different at the species level. Formerly they were treated as subspecies, *P. d. douglasii* for the Pygmy Short-horned Lizard and *P. d. brevirostris* for the Short-horned Lizard (or Eastern Short-horned Lizard) (Powell and Russell 1998). Hammerson and Smith (1991) corrected the spelling of *douglasii* to *douglasii* (or *douglasii*).
- ²⁵The European Wall Lizard (*Podarcis muralis*) is established in British Columbia (S. Orchard, personal communication), although it does not appear on most lists of North American species (e.g., Collins 1997). The French name was taken from: <http://www.bate-de-somme.org/reserve/naturelle.htm>.
- ²⁶The Racer (*Coluber constrictor*) is a wide-ranging and variable species whose taxonomy is not agreed upon by herpetologists. Some authors (e.g., Collins 1997) treat the western subspecies (*C. c. mormon*) as a distinct species, *Coluber mormon*. The Blue Racer (*C. c. foxii*), endangered in Ontario, is recognized as a valid subspecies by some authors (e.g., Cook 1984; Conant and Collins 1991), but included within the Yellow-bellied Racer (*C. c. flaviventris*) by others (e.g., Collins 1997).
- ²⁷COSEWIC considers the Blue Racer (*C. c. foxii*) Endangered (Ontario), the Eastern Yellow-bellied Racer (*C. c. flaviventris*) Special Concern (Saskatchewan), and the Western Yellow-bellied Racer (*C. c. mormon*) Not at Risk (British Columbia).
- ²⁸Some authors (e.g., Collins 1997; Harding 1997) recognize the Eastern Fox Snake subspecies (*E. v. gloydi*) as a separate species, *Elaphe gloydi*.
- ²⁹Until recently placed in the genus *Ophiodon* (see Oldham and Smith 1991).
- ³⁰The Lake Erie Water Snake (*N. s. insularum*) has a COSEWIC Endangered status (Ontario). The Northern Water Snake (*N. s. sipedon*) is the subject of a COSEWIC report in preparation.
- ³¹Western *Pituophis* were recently split at the species level, as *P. catenifer*, from eastern members of the genus (*P. melanoleucus*) (Collins 1997).
- ³²The sole Canadian specimen of *Sonora semiaurata* is presumed to be an introduction (S. Orchard, personal communication).

TABLE 2. Global status of Canadian amphibian and reptile species as designated by the IUCN and the ABI Network.

IUCN Designation							
ABI G rank	EX	Threatened			NT	No Designation	Total
		CR	EN	VU			
GX	0	0	0	0	0	0	0
G1	0	1	0	0	0	0	1
G2	0	0	0	0	0	1	1
G3	0	0	3	1	0	2	6
G4	0	0	1	1	1	7	10
G5	0	0	0	1	2	71	74
G?	0	0	0	0	0	1	1
TOTAL	0	1	4	3	3	82	93

¹Range ranks in the ABI system (e.g., G3G4) are treated here as the higher rank (e.g., G3).

Under the ABI system, the majority of Canadian species have no global conservation concern, with 80% (74 of 93) being ranked G5. Another 10 species (11%) are ranked G4, which although "apparently secure" globally, are of possible long-term conservation concern. In the IUCN system 88% (82 of 93) of Canadian amphibians and reptiles have no designation; however, it is not possible to distinguish species that were ranked LC from those that were not examined by the IUCN (1996).

National Scale

IUCN vs. ABI: We were able to assign national ranks using the ABI system to all 93 species that occur in the wild in Canada (Table 1). However, there were eight species that did not fall into any IUCN category. Under the ABI system, these species were ranked NA, NE, NR, or NZ (Table 4). The IUCN system is not designed to accommodate exotic species or species that do not occur regularly (such as most sea turtles in Canada); therefore, we were unable to assign IUCN ranks to these species. At the national scale, a considerably smaller proportion of the Canadian amphibian and reptile species have some degree of conservation concern status under the IUCN system (which we define as the following categories: RE, CR, EN, VU, NT, CD or DD; 24 of 93 species = 26%) than under the ABI system (which we define as the following categories: N1-N3, NH, or NX; 34 of 93 species = 37%) (Table 4). All 24 of the species with some concern under the

IUCN system were ranked N1-N3, NH, or NX using the ABI system. The six N1 species were either CR, EN, or VU, while the nine N2 species were either EN, VU, or NT. Ten of fifteen N3 species were LC, with five others ranking NT. All the N4 (n = 22) and N5 (n = 29) species were LC. Of the four species ranked RE under the IUCN system, two were ranked NX under the ABI system, and two were ranked NH.

Conversely, the only species ranked CR was N1 (Oregon Spotted Frog), while all ten EN and VU species were either N1 or N2. NT corresponded only to N2 or N3. There were no CD or DD species. LC corresponded to N3, N4 or N5. As the national rank increases using one system, it tends to increase using the other system. However, quite a bit of variability exists, and as at the global level, it is not possible to determine a species' rank under one system by merely knowing the rank under the other – the only way to find out is to evaluate the species against the criteria.

The correspondences between the two ranking systems that we obtained are shown in Table 5. The main difference between the two systems nationally is that 10 species considered to be nationally vulnerable using the ABI system (N3) were not considered to be of concern in the IUCN system (all were ranked LC). Otherwise, the correspondence seems good.

COSEWIC vs. IUCN: Forty of the 93 (43%) Canadian amphibian and reptile species have been examined by COSEWIC. Of these, 29 have been

TABLE 3. Global ranking category correspondence between the IUCN ranks and the ABI ranks for the Canadian amphibian and reptile species with both ranks. Sample sizes are shown in ().

IUCN VS. ABI	ABI VS. IUCN
CR=G1 (1)	G1=CR (1)
EN=G3 (3) or G4 (1)	G2=? (0)
VU=G3 (1), G4 (1) or G5 (1)	G3=EN (3) or VU (1)
NT=G4 (1) or G5 (2)	G4=EN (1), VU (1) or NT (1)
	G5=VU (1) or NT (2)

TABLE 4. National status of Canadian amphibian and reptile species: IUCN designations vs. ABI ranks.

N rank ¹	IUCN Designation							
	RE	Threatened			NT	LC	No Designation	TOTAL
		CR	EN	VU				
NX	2	0	0	0	0	0	0	2
NH	2	0	0	0	0	0	0	2
N1	0	1	2	3	0	0	0	6
N2	0	0	2	3	4	0	0	9
N3	0	0	0	0	5	10	0	15
N4	0	0	0	0	0	22	0	22
N5	0	0	0	0	0	29	0	29
NZ	0	0	0	0	0	0	1	1
NA	0	0	0	0	0	0	2	2
NE	0	0	0	0	0	0	4	4
NR	0	0	0	0	0	0	1	1
TOTAL	4	1	4	6	9	61	8	93

¹Range ranks in the ABI system (e.g., N3N4) are treated here as the higher rank (e.g., N3).

given a conservation concern status (X, E, T, or S) (Table 6), eight have been designated N, and five have been split by COSEWIC. However, 23 other species have reports in preparation (Table 1). Thirty species have not been examined and do not have reports in preparation.

Not including the species given split designations by COSEWIC, the proportion of Canadian species with some concern status at the national scale according to the COSEWIC designations (29 of 88 = 33%) is similar to the number determined using the IUCN system (27 of 93 = 29%) (Table 6). However, it is not possible to accurately predict the number of additional species that would be assigned a concern status by COSEWIC were the rest of the species examined. Of the 29 species that have been examined and assigned a conservation concern status by COSEWIC, 19 (66%) have a national concern status as determined by applying the IUCN criteria. The remaining nine species are ranked LC (six are S and three are T). It appears that there is not very good correspondence between the ranks obtained using the two systems (Table 7). For example, examining the COSEWIC category with the highest sample size (16), a species designated S by COSEWIC could have any of four possible IUCN ranks (EN, VU, NT, or LC).

COSEWIC vs ABI: Not including the species given split designations by COSEWIC, fewer species have some degree of conservation concern at the national scale as designated by COSEWIC (29 of 88 = 33%) than as determined using the ABI system (37 of 93 = 40%) (Table 8). However, it is unknown how many other species would be designated of concern by COSEWIC if the rest of the species were to be examined. Of the 29 species with concern status assigned by COSEWIC, all ranked N1-N3, NH, or NX using the ABI system (Table 9). All five N4 and N5 species examined thus far by COSEWIC were designated N. Thus there seems to be excellent correspondence between the COSEWIC and ABI systems.

Discussion

Our results suggest that the IUCN and ABI systems do not always correspond well at the global scale. That 27% of the species of global concern under the IUCN system were of no global concern under the ABI system (G5) was particularly surprising. For example, the Spotted Turtle was ranked VU by the IUCN due to past and projected habitat declines and levels of exploitation (IUCN 1996), whereas the G5 rank was based on the species' wide distribution, and

TABLE 5. National ranking category correspondence between the IUCN system and the ABI system. Sample sizes are shown in ().

IUCN VS. ABI	ABI VS. IUCN
RE = NX(2) or NH (2)	NX = RE (2)
CR = N1 (1)	NH = RE (2)
EN = N1 (2) or N2 (2)	N1 = CR (1), EN (2) or VU (3)
VU = N1 (3) or N2 (3)	N2 = EN (2), VU (3), NT (4)
NT = N2 (4) or N3 (5)	N3 = LC (10) or NT (5)
LC = N3 (10), N4 (22) or N5 (29)	N4 = LC (22)
	N5 = LC (29)

TABLE 6. National status of Canadian amphibian and reptile species: COSEWIC designations vs. IUCN designations.

IUCN Designation	COSEWIC Designation or report status								
	X	E	T	V	N	split by COSEWIC	in prep.	not desig.	Total
RE	1	1	0	0	0	0	2	0	4
CR	0	1	0	0	0	0	10	0	1
EN	0	1	1	2	0	0	0	0	4
VU	0	1	2	2	0	0	1	0	6
NT	0	0	1	6	0	0	2	0	9
LC	0	0	2	6	8	5	17	23	61
NO DESIG.	0	0	0	0	0	0	1	7	8
TOTAL	1	4	6	16	8	5	23	30	93

the fact that it is locally common in many areas but apparently declining in some areas (TNC 1998*). The difference may be due to differing interpretations of the available trend information (which is often very scanty) and/or to different availability of data. Other examples are the Eastern Box Turtle and the Slider, both ranked G5 and NT. We do not know the cause for concern for these two turtles by the IUCN because the criteria that are almost met by species ranked NT are not published (IUCN 1996). Both species are common in the pet trade in Europe and it is possible that this threat is the cause for the NT IUCN rank; however, both are locally common species in parts of the southeastern United States, both have wide North American distributions, and are considered to be demonstrably secure nationally in the U.S. and in at least 10 states where they occur.

At the national scale, a smaller proportion of the Canadian amphibian and reptile species is of concern under the IUCN system than under the ABI system. The ABI system thus appears to be more sensitive than the IUCN system at the lower risk level, while the IUCN system focusses on the levels of higher risk. Nevertheless, there was fairly good correspondence between the IUCN and ABI systems at the national level in that all 24 of the species with some concern under the IUCN system were ranked N1-N3, NH, or NX under the ABI system. In addition, all 61 species ranked LC under the IUCN system were ranked N3, N4 or N5. Thus, species ranked NX, NH, N1 or N2 always had an IUCN rank of concern, whereas N4 and N5 species were always ranked LC. We have no reason to suspect that this would not

also be the case with other taxonomic groups.

Because only 40 of 93 Canadian amphibian and reptile species have been evaluated by COSEWIC, it is more difficult to make the same comparisons that we were able to make between the IUCN and ABI systems, for which we ranked all Canadian amphibian and reptile species. Nevertheless, there does not appear to be good correspondence between the COSEWIC system and the IUCN system, however there is good correspondence between the COSEWIC system and the ABI system.

While the ABI ranks species at three geographic scales (global, national and sub-national), COSEWIC functions only at the national scale. The IUCN ranks species primarily at the global scale, but recently some countries have applied the IUCN criteria at the national scale. The IUCN system has no restrictions regarding allowable national ranks based on the species' global rank. Therefore, a species ranked EN by the IUCN (at the global scale) could presumably be ranked higher (e.g., CR) or lower (e.g., VU) in a particular country. (In the upcoming guidelines for applying the IUCN criteria at a regional (i.e., sub-global) level, it will be recommended that the threat category should never be lower on a regional scale than on the global level (U. Gardenfors, IUCN, personal communication). Under the ABI system, a species cannot have a higher rank at a lower scale (e.g., G3N4 is not allowed). If new information strongly suggests that an N4 is warranted in a country, then the evaluator of the national rank recommends that the GRANK be changed to G4. Discussion ensues until a consensus is reached.

TABLE 7. National ranking category correspondence between the IUCN system and the COSEWIC system.

IUCN VS. COSEWIC	COSEWIC VS. IUCN
RE = X(1) or E(1)	X = RE
CR = E(1)	E = RE(1), CR(1), EN(1), or VU(1)
EN = E(1), T(1), S(2)	T = EN(1), VU(2), NT(1), or LC(3)
VU = E(1), T(2), S(2)	S = EN(2), VU(2), NT(6), or LC(6)
NT = T(1) or S(6)	
LC = T(3), S(6), or N(8)	

TABLE 8. National status of Canadian amphibian and reptile species: COSEWIC designations vs. ABI criteria.

	X	E	T	V	N	split by COSEWIC	in prep	not desig.	Total
NX	1	0	0	0	0	0	2	0	3
NH	0	1	0	0	0	0	0	0	1
N1	0	2	0	1	0	0	2	0	5
N2	0	0	3	7	0	0	1	0	11
N3	0	0	3	8	1	0	5	0	17
N4	0	0	0	0	4	2	12	1	19
N5	0	0	0	0	1	2	4	22	29
NZ	0	0	0	0	0	0	0	0	0
NA	0	0	0	0	0	0	0	3	3
NE	0	0	0	0	0	0	1	3	4
NR	0	0	0	0	0	0	0	1	1
TOTAL	1	3	6	16	6	4	27	30	93

One advantage of this restriction is that it can simplify the ranking process. For example, assigning an NRANK to the Oregon Spotted Frog was simplified for us by the fact that this species is known in Canada only from British Columbia. Given that the provincial rank was S1, and that we had no reason to doubt that rank based on the available information, the NRANK had to be N1. The ranking process using the ABI system was thus facilitated greatly by the fact that GRANKS had already been assigned to all the species (except for ones recently recognized), and that SRANKs had already been assigned for all Canadian provinces. NRANKs could have been assigned before the creation of any CDCs, just as GRANKs are assigned even though not every country in the world has a CDC, but the process was simplified by having ranks at both scales.

Another advantage of ranking species at several geographic scales is that it aids decision-making with regard to the usefulness of conserving "peripheral species" (i.e., species with small Canadian distributions that are at the edge of more extensive U.S. ranges). In Canada, conservation concern for two species ranked N3 can be differentiated by considering their global ranks. Thus, a species ranked G3N3 would have higher conservation priority than one ranked G5N3.

Both the IUCN and COSEWIC systems rely heavily on population declines in order for a species to qualify for risk status. In the IUCN system, three of the five criteria require a decline (observed, suspect-

ed or projected), while in the COSEWIC system there must be evidence of a current decline for a species to obtain either of the two higher ranks. In the ABI system, trend is only one of six criteria — if there is no information on population trends (which is often the case), a species can obtain a high rank based on few individuals, few occurrences, a very small range, and/or considerable threats. A big difference between the IUCN and ABI systems is that all criteria are considered together in the ABI system (e.g., a small number of individuals is not to be considered the sole basis for making a decision unless no other information is available) while under the IUCN system one criterion (the one that gives the highest threat categorization) often determines the status assigned. Because all factors are considered together in the ABI system, a species with a very large population (e.g., >100 000 individuals) can be ranked G1 (e.g., if trends, range size, number of populations, or threats indicate the likelihood of extinction or extirpation), the kind of organism (e.g., mayfly vs. bear) which can greatly influence population size and other ranking criteria, is also considered under the ABI system. Another difference is that ABI ranks are continually reviewed and updated, as are the taxonomy and nomenclature that are used.

Some of the IUCN criteria (i.e., A, C1 and E) require a quantification of decline rate. In no instances in our ranking of amphibians and reptiles did we have enough information on decline rates to

TABLE 9. National ranking category correspondence between the Heritage system and the COSEWIC system.

ABI VS. COSEWIC	COSEWIC VS. ABI
NH = E(1)	E = N1(3), or NH(1)
N1 = E(3), or S(1)	T = N2(3), or N3(3)
N2 = T(3), or S(7)	S = N1(1), N2(7), or N3(8)
N3 = T(3), S(8), or N(1)	N = N3(1), N4(6), or N5(1)
N4 = N(6)	
N5 = N(1)	

TABLE 10. Proposed scheme for managers to use to combine national ranks obtained by applying the IUCN and ABI criteria independently.

IUCN Rank	IUCN Score	ABI Rank	ABI Score
RE	7	NX or NH	7
CR	6	N1	6
EN	5	N2	5
VU	4	N3	4
NT	3	N4	2
CD	2	N5	1
DD	2	NE, NZ, NA	0
LC	1		

apply any of these criteria. Thus the only criteria that we could use were B, C2 and D. Even though Criteria B2 and C2 require a continuing decline, this can be a decline of any rate, which facilitated the application of these two criteria.

Under the ABI system, whenever feasible, a complete species list for a taxonomic group (e.g., vertebrates, vascular plants, stoneflies) for a geographic area (e.g., North America) is developed and then all species in the group are ranked. All ranks and supporting documentation will be published in 2000 on a regularly updated public web site (<http://www.abi.org>). Neither the IUCN nor COSEWIC present such complete species lists. IUCN occasionally publishes Red Lists of Threatened Species (e.g., IUCN 1996, 1998), while COSEWIC annually publishes its revised list, which does include a list of species examined and not ranked. In contrast, IUCN does not publish a list of the species that were examined but not deemed to be Threatened or Near Threatened. In the case of amphibians and reptiles, for example, it is not possible to determine from the most recent global Red List (IUCN 1996) whether a species not listed was examined. Even in the case of mammals and birds, all species of which were examined (IUCN 1996), the absence of the list of undesigned species makes it impossible to know which taxonomy was used when the ranking was done (e.g., whether the ranking was done before or after a species was split into two species, one of which could have kept the old name). Another problem is that a person looking up a species in a Red List and not finding it could easily assume that the species was not listed, when in fact it was, but under a different scientific or English name. ABI makes available lists of synonyms of commonly used scientific names, which allows a species to be found regardless of the name used for the search. COSEWIC's annual list presents all the species that have been examined, distinguishing between species considered to be at risk and those that are NAR (Not at Risk). Yet, in every taxonomic group there are many species that have not been examined, and in general, COSEWIC does not provide "preliminary

statuses". The recent appearance of lists of rare Canadian lichens (Goward et al. 1998) and mosses (Belland 1998) is an excellent way of providing information on the Canadian status of rare species in these groups, in advance of formal designation by COSEWIC. These publications either suggest an appropriate national status using the COSEWIC system (Goward et al. 1998) or provide national ranks using the ABI system (Belland 1998).

It should be noted that the ABI uses its ranking system to rank ecological communities as well as species, and the inclusion of ecological communities was a factor in the original design of the ranking criteria. The IUCN system was designed specifically to rank species, and it uses certain concepts that were not meant to apply to ecological communities (e.g., population size) (G. Mace, IUCN, personal communication). This contributes to the substantial difference between the two ranking systems. The current COSEWIC system is not designed to accommodate assigning statuses to ecological communities.

The protection of ecological communities is crucial to TNC's strategy of protecting biodiversity, which is based on a coarse filter/fine filter approach. The coarse filter entails protecting at least one example of each ecological community, regardless of whether it is known to contain any rare species. This ensures the protection of a large proportion of existing plant and animal species, including the less known taxa (many invertebrates and non-vascular plants) (Ponomarenko and Alvo 1999*). The fine filter, on the other hand, is used to protect species that fall through the coarse filter — on a species-by-species basis. Rare ecological communities are of higher priority to protect than common ones; thus, it is important to have a ranking system that can be applied not only to species but also to ecological communities.

The correspondence between the IUCN and ABI systems at the global scale has been examined for all the species in the U.S. that have been ranked under both systems (mostly mammals, birds, and freshwater mussels). This analysis (Master et al. 2000) demonstrates that the IUCN ranks tend to be more

TABLE 11. National ranks of Canada's amphibian and reptile species obtained by combining the ranks using the IUCN system and the ABI system using our proposed scheme.

	IUCN Rank	IUCN Score	ABI Rank	ABI Score	Combined Score	COSEWIC
AMPHIBIANS						
Salamanders						
Northwestern Salamander	LC	1	N4N5	1.5	2.5	N
Jefferson Salamander	NT(B)	3	N2	5	8	*1
Blue-spotted Salamander	LC	1	N5	1	2	—
Long-toed Salamander	LC	1	N5	1	2	—
Spotted Salamander	LC	1	N5	1	2	—
Smallmouth Salamander	VU(D2)	4	N1	6	10	S
Tiger Salamander	LC	1	N5	1	2	*
Clouded Salamander	LC	1	N4	2	3	*
Dusky Salamander	LC	1	N3N4	3	4	N
Mountain Dusky Salamander	VU(D2)	4	N2	5	9	S
Pacific Giant Salamander	EN(C2b)	5	N2	5	10	S*
Ensatina	LC	1	N4	2	3	N
Northern Two-lined Salamander	LC	1	N5	1	2	—
Spring Salamander	NT(B,D1,2)	3	N2	5	8	S
Four-toed Salamander	LC	1	N4	2	3	N
Mudpuppy	LC	1	N4	2	3	N
Eastern Newt	LC	1	N5	1	2	—
Redback Salamander	LC	1	N5	1	2	—
Coeur d'Alene Salamander	EN(D1)	5	N2	5	10	S
Western Redback Salamander	LC	1	N4	2	3	*
Red Salamander	—	—	NEX	—	—	—
Roughskin Newt	LC	1	N4N5	1.5	2.5	—
Frogs and Toads						
Northern Cricket Frog	RE	7	NH	7	14	E*
Tailed Frog	LC	1	N3N4	3	4	E, S
American Toad	LC	1	N5	1	2	—
Western Toad	LC	1	N4	2	3	*
Great Plains Toad	LC	1	N3	4	5	S
Fowler's Toad	EN(B1,3d)	5	N2	5	10	T
Canadian Toad	LC	1	N4	2	3	*
Cope's Gray Treefrog	LC	1	N4	2	3	N
Gray Treefrog	LC	1	N5	1	2	—
Spring Peeper	LC	1	N5	1	2	—
Pacific Chorus Frog	LC	1	N5	1	2	—
Western Chorus Frog	LC	1	N5	1	2	*
Red-legged Frog	LC	1	N3N4	3	4	S
Bullfrog	LC	1	N5	1	2	—
Green Frog	LC	1	N5	1	2	—
Columbia Spotted Frog	LC	1	N4	2	3	N
Pickereel Frog	LC	1	N5	1	2	N
Northern Leopard Frog	LC	1	N5	1	2	E, S, N
Oregon Spotted Frog	CR(B1,2)	6	N1	6	12	E
Mink Frog	LC	1	N5	1	2	—
Wood Frog	LC	1	N5	1	2	—
Plains Spadefoot	NT	3	N3N4	3	6	S
Great Basin Spadefoot	LC	1	N3	4	5	S
REPTILES						
Turtles						
Spiny Softshell	VU(C2aD1)	4	N2	5	9	T
Loggerhead	—	—	NA	—	—	—
Green Turtle	—	—	NA	—	—	—
Common Snapping Turtle	LC	1	N5	1	2	—
Painted Turtle	LC	1	N5	1	2	—
Spotted Turtle	NT(C,2a)	3	N3	4	7	S

(Continued)

TABLE 11. (Concluded).

	IUCN RANK	IUCN SCORE	Heritage RANK	Heritage SCORE	COMBINED SCORE	COSEWIC
Wood Turtle	LC	1	N3	4	5	S
Western Pond Turtle	RE	7	NX	7	14	*
Leatherback	EN	5	N1N2	5.5	10.5	E*
Blanding's Turtle	LC	1	N4	2	3	T*
Common Map Turtle	LC	1	N4	2	3	*
Atlantic Ridley	—	—	NA	—	—	—
Common Musk Turtle	LC	1	N4	2	3	*
Eastern Box Turtle	—	—	NE	—	—	*
Slider	—	—	NE	—	—	—
Lizards						
Northern Alligator Lizard	LC	1	N4N5	1.5	2.5	*
Five-lined Skink	LC	1	N3	4	5	S
Northern Prairie Skink	NT(D2)	3	N2	5	8	S
Western Skink	LC	1	N4	2	3	*
Short-horned Lizard	RE	7	NH	7	14	X
Pygmy Short-horned Lizard	NT(B1,2)	3	N2N3	4.5	7.5	S
Common Wall Lizard	—	—	NE	—	—	—
Snakes						
Rubber Boa	LC	1	N3N4	3	4	*
Racer	LC	1	N4	2	3	E, S, N
Sharptail Snake	VU(D1)	4	N1	6	10	E
Timber Rattlesnake	RE	7	NX	7	14	*
Western Rattlesnake	LC	1	N3N4	3	4	*
Ringneck Snake	LC	1	N5	1	2	—
Eastern Rat Snake	LC	1	N3	4	5	T
Fox Snake	NT(C)	3	N3	4	7	T
Western Hognose Snake	NT	3	N3	4	7	*
Eastern Hognose Snake	LC	1	N3	4	5	S
Night Snake	VU(B1,2)	4	N1	6	10	*
Milk Snake	LC	1	N5	1	2	*
Smooth Green Snake	LC	1	N5	1	2	—
Northern Water Snake	LC	1	N5	1	2	E*
Gopher Snake	LC	1	N3	4	5	*
Queen Snake	VU(C2a)	4	N2	5	9	T
Massasauga	LC	1	N3	4	5	T
Ground Snake	—	—	NRF	—	—	—
Brown Snake	LC	1	N5	1	2	*
Redbelly Snake	LC	1	N5	1	2	—
Butler's Garter Snake	NT(B1,2)	3	N2	5	8	S
Western Terrestrial Garter Snake	LC	1	N5	1	2	—
Northwestern Garter Snake	LC	1	N4	2	3	*
Plains Garter Snake	LC	1	N5	1	2	—
Eastern Ribbon Snake	LC	1	N4	2	3	*
Common Garter Snake	LC	1	N5	1	2	—

¹ * = COSEWIC status report or status update report in preparation.

conservative. This is perhaps due in part to the greater emphasis on trend information, which is in short supply for many species, the greater IUCN emphasis on projected threats, which are used as a surrogate for projecting future trends, and less emphasis on population numbers and range size as indicators of vulnerability (L. Master, TNC, personal communication). Also in Stein et al. (2000) is a comparison of ABI ranks with the largely independently derived American Fisheries Society's (AFS) published lists of fishes, mussels, and crayfishes of concern in North America. In this case (ABI vs. AFS) the lists are very close in composition. Another paper is in preparation comparing IUCN, ABI, and Partners in Flight (PIF) scores for North America birds (L. Master, TNC, personal communication). After ranking 93 species using both the IUCN and ABI criteria, we cannot conclude that either system is superior. There are advantages to applying both independently, and there is no compelling reason

why the species should not be evaluated using both systems. This could provide a stronger justification for a status assignment for a species.

We suggest applying the two ranking systems separately and then combining them into a new national score. IUCN and ABI categories would receive numeric scores shown in Table 10, and the two scores would simply be added. The highest possible score would be 14, and would apply to species known or thought to be extirpated. N1, N2 and N3 would have the same values as CR, EN and VU, respectively. NT would be considered as being roughly equivalent to N3N4. At the low end, N5 and LC would be given the same rank because they both represent the species for which there is little immediate conservation concern. These species would be assigned 1 instead of 0 scores to indicate that there is some concern rather than none. The ranks intermediate IUCN and ABI categories would be assigned intermediate scores in between, with CD and DD receiving the same score. The gap between N3 and N4 seems reasonable because the 3-4 level is often the cut-off point separating the species for which all the occurrences in a jurisdiction are documented and the species for which this is not the case (e.g., many CDCs and Natural Heritage Programs "track" only S1-S3 species). Range ranks in the ABI system (e.g., N1N2) would receive an intermediate score (e.g., 5.5). Letter ranks under the ABI system (e.g., NA, NE) would be used to allow a complete species list to be developed with ranks for all of them, but these species would be given a score of zero.

Deciding which scores to assign to extirpated (RE or NX) and possibly extirpated (NH) species was problematic. We argue that such species should be a high priority for conservation attention (e.g., through reintroduction programs or field surveys to confirm or refute extirpation). Another difficult rank to assign a score to is Data Deficient (DD). A DD species could be very rare and in need of conservation attention, but there are insufficient data to assign it to a risk category. DD species should be high priority for research attention, i.e. studies should be undertaken to address the data deficiencies, so the species can be properly assigned to a status category. The premise underlying both ranking systems is that they both attempt to assess extinction/extirpation risk, but neither is meant to be used by itself as a system for setting conservation priorities as other factors must come into play (e.g., opportunity, funding). Another important factor to consider is "supervisory [or jurisdictional] responsibility", wherein a species is considered a higher conservation responsibility if a greater proportion of its global range lies within the jurisdiction (Dunn 1997).

Applying our proposed scoring system to Canadian amphibians and reptiles gives the results shown in

Table 11. Scores range from 2 (Least Concern N5 species) to 14 (extirpated or possibly extirpated species). Species that have been listed by COSEWIC have scores ranging from 5 to 14. Species for which COSEWIC status reports are in preparation have scores ranging from 2 to 14. Species that have not been examined by COSEWIC and do not have status reports in preparation range from 2 to 3.

Generally the outcome of this approach is that it provides a larger number of possible national categories than is the case with either the IUCN or ABI systems. National ranks thus assigned are more justifiable, given that more information is used to arrive at the new ranks than is the case if either of the two systems is applied alone.

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Book Reviews

ZOOLOGY

Models of Adaptive Behaviour

By Alistair I. Houston and John M. McNamara. 1999. Cambridge University Press, Cambridge. ix+378 pp. Cloth \$80.00, paper \$34.95.

Over the past couple of decades the efforts of these two English researchers have become well known in behavioural ecology. The approach is to view animals as systems of state variables and to see how behaviour can be understood as a dynamic maximizing of biological fitness. In this book over-viewing the approach, the stage is set by considering foundational topics including quantities such as reproductive value and trade-offs between (say) feeding and vigilance. The dynamic optimization of action over time is elaborated in terms of probabilistic futures and sensitivity of crucial variables. The book then proceeds through foraging (including dealing with competitors and environmental uncertainty), dynamic games (many aspects of which are particularly well examined), routines (such as timing of reproduction), and life history strategies in many contexts. The careful dissection of mate desertion during reproduction well demonstrates the power of an evolutionary games approach to such problems.

The main text is helpfully augmented by appendices, referencing, and indexing. Perhaps it is the richness of models investigated that prevented a glossary of terms. The review of material is wide and thorough, the employment of techniques such as iter-

ative solutions deft, and the evaluation of different arguments and models (both of the authors' and others) incisive. There is laudable attention to the limitations of models and to future directions for work such as physiological studies into mechanisms. To niggle, how does one "see Leimar (unpub.)" (page 169)?

This is very much an advanced and theoretical work presented in a dense and authoritative manner for an unspecified audience. The approach is general and abstract, with little regard to mundane details. Just as none of the mathematics is developed step-by-step, no real cases are presented at length. Issues of measurement in real systems to yield data, especially on the key matter of fitness, are at most implicit. Hence, workers with some prior familiarity in this domain will welcome this broad synthesis of problems and models, but newcomers will find significant challenges, perhaps having learned to wince at assurances such as "It can easily be shown that..." (page 56). Before beginning this book, have your Lagrange multipliers and Leslie matrices at hand. The mathematization of biology is not proving easy, and this volume indicates how tough it will be.

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A Practical Guide to Vertebrate Mechanics

By Christopher McGowan 1999. Cambridge University Press. Cambridge. 301 pp., illus. U.S. \$39.95.

We marvel at nature but rarely understand why nature works the way it does. We are familiar with the National Geographic television specials that highlight a specific ecosystem or individual species, but more often than not we can not comprehend the actual mechanics of an individual species. Why are birds bones different than a Mastodon, or for that matter, why are the physiques of long distance runners different than sprinters. Chris McGowan's *A Practical Guide to Vertebrate Mechanics* explores these questions for the student and teacher.

The book can be divided into two sections. The first is the make-up of the animal. Not just the nam-

ing of bones and muscles but the differing compositions of bones among vertebrates; the principles of allometric growth, the strength and elasticity of bone and tissues; or why they are positioned the way they are. As with all thirteen sections in the book, each ends with practical experiments, often using simple materials found around the house: no need for high tech machinery here. For example, when a hand pulls on a rope the elbow acts like a fulcrum, when the effort and load are on either side. A easy visual of this class 1 lever system is a pair of pliers. Or, after understanding some of the functions and limitations of bones and soft tissues, a natural history museum that includes extinct species, provides the opportunity to "visualize them as living animals . . .

about how they supported their mass, how they moved, what particular locomotory problems they faced, and how they solved these problems" (page 129).

The latter half of the book examines the species in motion, on land, in the air, and in the water, and with this, we find more relevance to the species evolutionary past. In considering aquatic movement, those that have stiff bodies generally tend to be faster than those that use their undulating bodies for propulsion. Yet, cetaceans illustrate "how phylogeny can place constraints on evolutionary opportunity" (p. 254), in that the tail flukes remain unsupported by bone. Whether in water, on land, or in the air, the importance of drag also sets some limitations. To illustrate how drag works, by molding some plastecine into various hand-sized shapes, at one end implanting a paper clip for a eyelet, these objects can be strung along in a bath tub. The obvious displacement of water illustrates which

shapes are conducive to motion without excess waste of energy.

When so many paleontologists have extended their practice by glorifying the tales of explorations or even of evolution, it is refreshing to follow the path that McGowan has taken with this book as well as in his earlier ones like *Make Your Own Dinosaur Out of Chicken Bones* (HarperCollins College, 1997), and even *Dinosaurs, Spitfires, and Sea Dragons* (Harvard University Press 1992). Each have marveled at the functions of extinct and extant species. Remembering that this recent tome is geared towards university level training, he remarks in the opening section that science should be fun and supplemented with hands-on practicums. And to this end, McGowan has certainly succeeded.

TIM TOKARYK

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A Birder's Guide to the Rio Grande Valley

By Mark Lockwood, William McKinney, James Paton, and Barry Zimmer. 1999. American Birding Association, Colorado Springsvii + 279 pp., illus. U.S. \$23.95.

It is close to twenty years since I first spoke to Jim Lane, the original author of many bird finding guides. Among other things I remember telling him of an "error" in his then new guide - I found the Caracara in the third, not the second palm tree! Jim, and then Harold Holt, continued to fill the much needed "how to find" gap for many years. Now it is the turn of a new group of enthusiasts.

This guide covers the Rio Grande valley along the Texas border from the Gulf of Mexico (Brownsville) to El Paso. The authors include some of adjacent New Mexico (and a tiny spike into Mexico), up river along the Pecos and inland to the Edwards plateau (around San Antonio). Thus they encompass some of the most exciting birding territory on the North American continent. It does not cover the Gulf Coast region that includes Laguna Atascosa, Padre Island, and Aransas. These are included in "*A Birder's Guide to the Texas Coast*" — another Lane birdfinding guide.

The text is set in sections that cover a specific birding locale (a park, reservoir, sewage plant, city dump) or a section of road. Clear and precise directions are given to each road and turnoff (Distances are given in miles not kilometres. This should not be a problem as most cars have both scales. Canadians should remember that a 100-mile drive does not take one hour!) Where appropriate landmarks, such as bridges, tree clumps etc., are given as a guide. The

nature of the road is described too. This is not only useful in assessing the driving difficulty, but is also helpful in verifying the route. For much of the book, directions are given as if you were driving from one spot to the next in sequence. However the authors have added directions for those who wish to drive to a specific spot directly from the main road.

Once you are at the site there are precise directions for trails, woodlots, fields and viewing areas. The particularly features of the trail, from how difficult it is to walk through the effects of weather to any special hazards, are specified. The authors note costs of entry and limits to access (highlighted in *Italics*). When prudent, the authors advise when to take water. This region does have hazards that must be considered by the prudent birder. Heat, rain, insects and other animals and our fellow humans included. The author's treatment of these hazards is not alarmist but sane and measured.

The book contains information on places to stay (motels and campgrounds), eat, and, where important, buy gas. There is also pertinent advice on washrooms, water availability, and other creature comforts.

The book's main function is to indicate the birds to be found at each locality, not just in the park or particular stop, but along each path or on each pond. Specific attention is paid to the specialties of each area, but all other species are treated fairly. Birds are further covered by season. The authors add as much useful detail to give the reader the best chance of being successful. This includes describing the habits

and habitat of specific species wherever this would be of value.

The authors have replaced the bar-graph checklist with an annotated checklist. They have done this with sound and logical reasons, yet I will miss the bar-graph. The annotated list covers all the species of birds in the region and highlights the regular specialties by using capital letters. Rarities are not highlighted. This works well, although I do not see why Chihuahuan Raven and perhaps Northern Jacana, Monk Parakeet, or Brown-crested Flycatcher are not highlighted.

Throughout the text there are brief snippets of history. There is additional information on maps, rare bird alerts, amphibians, reptiles, and mammals. The references include many on wild flowers. Compared

to my data the snake list looks about 25 per cent low and I was surprised that there was no reference to the atlas-like 1994 *Field Guide to the Birds of Texas* by Rappole and Blacklock.

This book contains a great wealth of information and is a "must" for those intent on exploring the magic section of Texas. At first the mass of information might seem overwhelming, but it is so well organized that effectively using the book is simple. Jim Lane and Harold Holt would be proud.

ROY JOHN

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Tundra Plovers: The Eurasian, Pacific and American Golden Plovers and Grey Plover

By Ingvar Byrkjedal and D. B. A. Thompson, illustrated by Ingvar Byrkjedal. 1998. T & AD Poyser Ltd., 24-28 Oval Road, London NW1 7DX. Distributed by Academic Press, San Diego. 422 pp., illus. U.S. \$34.95.

Many years ago, while undergoing an arduous basic military training, some of my few sources of delight were the plaintive calls of golden plover in the early mornings, from the frosty fields outside the barrack huts. Those birds were Eurasian Golden Plover, but since those days my life has been punctuated by tundra plovers of one species or another, sometimes giving joy where there was none, but more often adding a final defining touch to the delights of shorelines, moorlands, and tundra.

For many of us these elegant birds epitomize wild places, and we now have a major monograph by two ornithologists who clearly share this passion for them, and who manage to breathe some of that magic into their account of these birds' lives. This is a delightful book. Byrkjedal's delicate vignettes capture the characters of the different species, the black-and-white photographs offer an excellent selection of habitats, nests, and behaviour, and the well-written and intelligently organized text makes a scholarly treatise easy and fascinating reading.

All this might seem a strange start to a review of a comparative study of four closely-allied species of plover, but scientific treatises are usually read by — well, scientists — and this is a book that will appeal to a far broader audience. All that said, however, this really is a major work, drawing on years of field study by both authors, full of wholly new information, thought-provoking analysis, and awash with facts. Some prosaic statistics tell the tale: we have 38 pages of references, 16 tables

[segregated at the rear of the book], and 14 appendices, in addition to an abundance of text graphs, charts, and maps.

The text is organized into 14 chapters, starting with an introduction to the birds, followed by two dealing mainly with taxonomy, plumage, and [with Godtfred A. Halvorsen] phylogeny and biogeography. Then there are four chapters on various aspects of the breeding season, two on aspects of migration and ecology in the non-breeding season, and the book concludes with sections on diet, associations with other birds, and conservation.

The book has its full share of minor errors, and I'm sure that there is plenty in this formidable mass of discussion to stimulate controversy — in fact, the authors freely acknowledge this. A couple of examples will suffice: the population estimates for both Black-bellied and [particularly] American Golden Plovers are extremely high, and none of the figures I have seen imply populations of anything like these numbers. The authors have arrived at their figures by establishing average breeding densities for 'core' and 'marginal' areas respectively, and then dividing the breeding range up into these two categories. Populations are then derived by multiplying average densities by the areas. This seems plausible, but it involves some vast leaps of faith with regard to the distribution over enormous areas of habitat that few ornithologists have ever visited. Then the authors offer a field mark [bill length relative to head length] which is new to me, at least. It doesn't really seem to work on the photographs, so I'll probably have to wait until next fall to try it out in the field.

A more serious problem may lie in the fact that the authors' experience in North America is quite

limited — principally a year by Byrkjedal. While it's unfair to attribute weaknesses to the book on this basis, it is bound to influence the perspectives of the authors.

But then, no North Americans have essayed such an ambitious synthesis, and the present effort succeeds admirably on many fronts. It is an outstanding

achievement that should interest anyone who has felt the fascination of these delightful yet enigmatic birds.

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Starlings and Mynas

By Chris Feare and Adrian Craig, illustrated by Barry Croucher, Chris Shields, and Kamol Komolphalin. 1999. Princeton University Press, Princeton, New Jersey. 285 pp. illus. Hardback, US\$39.50

This survey is one of the current series on bird families, originally described as 'identification guides', and published initially in the U.K. It deals with the 114 species in the starling family, one that includes some of the world's most familiar birds, but also several species that are threatened with extinction. Both authors have studied starlings extensively, Feare having written a monograph on *The Starling*, and Craig researching African species for many years.

Like its predecessors, the book opens with a comprehensive review of the family as a whole. Taxonomy is covered in some detail in the first 14 pages, with the authors proposing revisions based on recent studies. The next 20 pages review distribution, behaviour, breeding and moult, and conclude with a good and quite extensive section on starlings and man. There are 22 pages of bibliography.

The bulk of the book is the species' accounts, which vary in length from a little over a half a page for localized and little-known species such as the White-faced Myna of Sri Lanka, to over six pages for the European Starling. The latter provides a good overview of this interesting species under a range of subheadings that again include Relations with Man. The accounts generally seem to offer similarly comprehensive treatments for all the species covered, although data are inevitably lacking on many of the less common ones.

The 32 plates illustrate 2-6 species on a page, often with attractive habitat vignettes added, and with a range map and a brief summary of identification features for each species on the facing page. Where relevant flight patterns are illustrated, as are plumage variations: there are seven images of the

Black-winged Myna, for example. Three artists contributed the illustrations, but only two plates by Kamol Komolphalin are signed. This is unfortunate, as the work presents a range of styles. The African plates offer the best treatments I have seen of these species [although the Golden-breasted Starling plate fails to do justice to this breath-taking bird]. The images are a good size, and the challenging glossy species are particularly well done. Some of the Asiatic plates appear to be by the same artist, but others are less successful, with the birds appearing wooden and lifeless. Komolphalin's work falls between the two, but the images on plate 12 are rather small.

Identification continues to be stressed as a feature of this series, and indeed the species accounts do include a section on Field Recognition. For many of the starlings real recognition problems rarely arise, but I selected two of the more difficult African species — the Greater and Lesser Blue-eared Glossy Starlings — and found the 9-10 line accounts rather cursory in comparison with, for example, the excellent treatment in the *Birds of Kenya and Northern Tanzania* [1996, Zimmerman, D. A., D. A. Turner, and D. J. Pearson]. By contrast the identification details on Spotless Starling are comprehensive and informative, so here too the coverage appears to be rather uneven.

These criticisms apart, the book succeeds well as a definitive guide to the starling family. Its direct value to a North American audience will be rather limited, given that we have only four introduced species, but it will be of interest to anyone who wishes to know more about this fascinating and diverse array of birds.

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Handbook of the Birds of the World: Volume 5 Owls to Hummingbirds

Edited by Josep del Hoyo, Andrew Elliot, and Jordi Sargatal. 1999. Lynx Edicions, Barcelona, Spain. 759 pp., illus. U.S.\$185.

This volume of *Handbook of Birds of the World* (HBW5) covers some of the most difficult to observe birds and some of the most brilliant and visible. The volume begins with owls, which have been a source of discussion and dissension among taxonomists for many years. The authors have decided, based on the latest evidence to place them next to the bizarre nighthawk-nightjar group. In addition to the owls, this edition of HBW contains accounts of the weird oilbirds, the cryptically camouflaged nightjars (including our own nighthawks and 'wills), and the dazzling hummingbirds.

As difficult as it is to decide on where owls fit within the order of birds, I have even more trouble with defining a species. The text on speciation while thorough and based on current, strong scientific evidence still leaves me wondering. For example, the widely distributed Common Barn Owl has a large number of colour variants, many of which are well illustrated in HBW5. The variation is so broad that it is difficult to distinguish some of the variants from other species of related Bay and Grass Owls. Fortunately, those that most closely match seem to all live far apart. I still wonder if this is really a question of geographical variation though. Given these types of geographical variations and the difficulty of seeing owls well, I am not surprised at those who misidentified the two most recent US sightings of Stygian Owl as a Long-eared Owl.

HBW5 contains illustrations of a significant number of identifiable subspecies. I was particularly pleased to see a rendition of *B.v. arcticus* subspecies of the Great Horned Owl. This illustration matches a bird I had seen in central Saskatchewan some years ago. It was much darker than an owl I saw in southern Manitoba about two years ago. This latter bird at first suggested a Snowy Owl but it was sitting in a woodcut in summer. Closer inspection showed it to be a Great Horned Owl and I now think it was an albino. HBW5 continues with Oilbirds, Owlet-nightjars, Frogmouths, Potoos, and Nightjars. The strange Oilbird seems out-of place in any taxonomy. While similar to owls and the nightjar clan in some ways, in others the Oilbird is unique. A fruit eater, it finds its way by sonar, sight, and possibly smell. Its cousins the owlet-nightjars, of New Guinea and Australia, do at least look like a cross of an owl and a nightjar. From what little is known of these birds, they appear to behave like other nightjars and catch insects. The Frogmouths are another S.E. Asian and Australian group, renowned for their cryptic camouflage. Again they are similar to nightjars although some of the larger ones eat vertebrate prey. The

related Potoos are the South and Central American representative of this weird clan. The final group of these crepuscular birds is the widespread Nightjars, and include the species with which I am most familiar. "Familiar" is perhaps too strong a term in this instance. The only species I have actually seen well enough to study is the Common Nighthawk. On reflection, I now realize I have identified the other species by location, behaviour, and most importantly, voice. My typical Whip-poor-will sighting is of a calling bird sitting on a road in the colour-distorting glare of headlamps.

Swifts, the next group to be covered, are diurnal insect hunters and therefore much easier to see than nightjars. Despite their name, I have long believed swifts were not fast fliers, but were very acrobatic. I was surprised to see claims of up to 170 km/h quoted. I thought these high speed records had been refuted long ago. Indeed, using data given for migratory passages in this book suggest the typical speed is probably less than 20 km/hr. I was also puzzled why more attention was not paid to the nest box program for Common Swifts. This is underway in select locations from Europe to Israel and appears to be improving swift numbers.

The final section of this volume covers the hummingbirds and their allies. This very large family of at least 328 species of birds occurs throughout North and South America. I found the nesting section of the text most interesting. Perhaps this relates to the difficulty I have had when I have tried to point out a hummingbird nest to someone. Although the material covered was considered and comprehensive, I was surprised the remarkable and unique aerial display flights of male hummers was not covered in any depth.

I found the illustrations in this edition more difficult to judge. As I have said, I have rarely been able to make a study of members of the secretive nightjar clan. Owls are somewhat more easily observed and I thought the owl plates to be accurate in both shape (owls can look oddly shaped at times) and colour. The perkiness of the Burrowing is nicely captured, for example. I can say the same thing about the swift plates. I was however disappointed in some of the paintings of the hummingbirds. These are vibrantly coloured birds, but this does not always come across. I realize it is difficult to capture iridescence on paper, yet I have seen more luminous renditions of hummers. Indeed, the last volume, HBW4, contained some wonderful plates of parrots, an equally vibrant group of birds.

The photographs are quite wonderful. Not only those that are portraits of individuals, but those that depict habitat are of high quality. For the swifts, many of which nest in spectacular places, the habit photos are very useful. Many of the photographs of

hummingbirds are amazing and give a much better idea of the vibrancy of their plumage. In some cases the birds are given colorful competition by the flowers they are feeding on; lantanas, bromeliads, heliconias, hibiscus, trumpet vines, and powder puffs. I must particularly mention a startling pair of photos showing a strike (unsuccessful) by an eyelash viper wrapped around a scarlet heliconia, towards a hummingbird. The cryptic camouflage of most of the species in this edition comes out very well in many of the photos. This is particularly true of the frogmouths. I remember an occasion when I spent 40 minutes pointing out a sleeping Common Nighthawk to a group of people. Despite the fact it was motionless and only seven metres away it proved difficult for many to "see." There is a photo of a Common Barn Owl floating over a winter field that captures the image of a ghostly vision so typical of this bird.

I normally feel that the quality of the illustrations are a vital component of this type of book. However, in this edition, perhaps because of the similarities in plumage and the missing vibrance I found I was more drawn to the text. The text is authoritative and well researched and contains some remarkable information. Did you know the two species of fairy (hummingbirds) drift off their nests like falling leaves? This seems to be a predator defense. Once away from the nest they fly normally.

So I can think of three reasons to buy this book; to continue with your collection of the series; if you are studying owls, the nightjars group or swifts, and if you simply want a good read.

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Birds of Kenya and Northern Tanzania Field Guide Edition

By Dale A. Zimmerman, Donald A. Turner, and David J. Pearson. 1999. Princeton University Press, Princeton, N.J. 576 pp., illus. Cloth U.S.\$39.50; paper U.S.\$29.95.

The original full length *Birds of Kenya and Northern Tanzania* was published in 1996. It contained 740 pages and weighted just under 2 kg, which probably meant some hard decisions when packing a day backpack. Now that this field edition is available, you can take your lunch AND the field guide, which weighs half a kilo. Some details which were in the original have had to be omitted or abridged, and the authors stress that this new guide is not a substitute for the original. The lengthy discussions of climate and habitats, and the appendices, gazetteer, and bibliography have been omitted. However, habitat definitions are still included. Species accounts are about half the length of the original, and subspecies have been condensed. Literature references have been deleted, the glossary is smaller and range statements reduced, but distribution maps have been retained, as have all the original colour plates. There are 34 Tanzanian species added which are found in the Serengeti and Tanzania national parks and the Usambara Mountains. Over 80% of the Kenyan species occur in Uganda Ethiopia, Somalia, Sudan, and Tanzania so that this one guide would probably suffice for an extensive field trip in East Africa. There is unconventional placement of some small families, such as weavers, to facilitate plate arrangement. This is sensible when

you are trying to identify, say, a buff-breasted, brown streak-backed widowbird from a very similar *Quelea*. In spite of the compressed, but very clear, illustrations, it was wise to retain male, female, and juvenile plumages for the majority of the 1084 species illustrated. The rewritten and condensed species accounts give a longer description than the brief one given opposite the illustration and there is a range map, but the accounts do not follow the same order as the illustrations. The end page inside the front cover has a map of Kenya and Northern Tanzania national parks, towns, and game reserves. Inside the back cover is a clear map of the physical features of the whole area. The intention of this guide is to facilitate identification in the field; the comprehensive original book can be consulted at leisure. English names and scientific names are given in separate indices.

Dr. Roger Titman, Ornithology Professor at McGill, used this guide during a February 2000 field course in Kenya, and reports: "The illustrations are superb and so accurate that, even though the descriptions are inadequate, you can easily identify a bird."

It is an admirable effort to have condensed so much without losing integrity and to provide a valuable field guide.

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Fishes of Nova Scotia: Species Recorded in the Accession Books of Harry Piers from 1899 to 1939

By John Gilhen. 1999. Museum of Natural History, Nova Scotia Museum, Nova Scotia Department of Tourism and Culture. Curatorial Reports (89): 1-153, 107 plates.

In cramped offices and labs, with penurious financial support, devoted natural history museum curators, like Harry Piers of the Nova Scotia Museum of Natural History, built the foundations of knowledge in the natural sciences. Harry Piers worked for 40 years advancing the state of knowledge, communicating with his peers in other institutions, and providing a valuable service to the province.

Harry Piers collected fishes himself, purchased some, encouraged others to make donations. His harvest included teeth from a great white shark which attacked and left its teeth in the rowboat of a fisher, down to the small-sized rainbow smelt and pipefish. He accessioned, identified, and conserved the specimens. He corresponded with scientists like Phillip Cox and David Starr Jordan to ensure identifications and nomenclature were correct. He added 13 species of fishes to the known ichthyofauna of Nova Scotia.

The older documentation provided by assiduous museum records like those compiled by Piers, is important. They establish the occurrence and status of species, then common, now rare or endangered. For example the Acadian whitefish he first reported, as the Sault white-fish, is now classed as endangered, and the big skate populations, healthy in those days, are now greatly diminished due to trawling. Museum specimens have the advantage over literature records, in that one can return to verify the identification and so certify the original identification was correct — or not so, or that it was a species then not known to science.

Following an instructive Foreword and Introduction, Gilhen provides an annotated list of Pier's fish accessions, with accession numbers, name, location, and other data. These data are sometimes enriched by references to supplementary information drawn from correspondence, publications, newspapers, or other sources. We learn about the habits of the Acadian whitefish, prone to leap 2 to 6 inches

out of the water after flying insects, fishing methods for bluefin tuna (weirs and harpoons), and the capture of the first tarpon from Canada. Following the list are 107 plates. The plates document the accessioning methods, correspondence, drawings of specimens with measurements, and photos of interesting specimens.

One myth John explodes is handwriting. We are given to understand from our elders that Pier's was the age of beautiful copper-plate script handwriting. But Pier's handwriting, a challenge to the interpreter, kept to the standards of the medical doctor in writing prescriptions.

This book carefully documents Pier's contributions in ichthyology, but mentions also that this pioneer was active in tracing master gold- and silver-smith marks, was active in artists' and authors' societies, and was the Nova Scotia representative of the Geographic Board of Canada.

John Gilhen is to be commended for documenting the rich contributions that Harry Piers made to Nova Scotia ichthyology, and the Museum of Natural History for publishing this record. Hopefully this will lead to a better understanding of roles of natural history museums, their curators and technicians in society. It is seldom that museums, known more for their modesty than celebrating their own, document what they provide for the understanding of nature and the edification of humankind. John Gilhen has brought to his task the experience of many years in curatorial work in ichthyology and herpetology at the Nova Scotia Museum. This shows in the well-rounded evaluation of the works of Harry Piers.

Perhaps in the New Millennium, governments will begin to bolster instead of cutting back the human and other resources needful to understanding the natural world in which we all live.

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ENVIRONMENT

Quantitative Analysis of Movement

By Peter Turchin. 1998. Sinauer Associates, Sunderland, Massachusetts. ix+396 pp., illus. U.S.\$18.95.

A central problem for all naturalists is how organisms of interest get from one place to another. In this

book Turchin, a mathematical ecologist at the University of Connecticut, laudably aims at a popular account of spatial dynamics strategically using models linking theory and data. First described are types of observations and models. Behaviourally-

based models focus on random walks and diffusion involving orienting mechanisms. The analysis of movement paths includes spatial heterogeneity and fractals. The problems in the method of mass mark-recapture, such as loss of organisms, are evaluated. Under individual mark-recapture, the discussion on the spotted owl and corridors among islands of habitat well demonstrates the importance of this topic for conservation biology. Throughout there is careful attention to empirical issues, such as social influences, and statistical ones such as approximations and independence. In each chapter the theory is illustrated with fully discussed examples from both animals and plants, and earlier work is carefully critiqued. The full bibliography, glossaries, and appendix with mathematical details are useful features of the volume.

While wanting a popular account, Turchin correctly avoids any dumbing down of the issues. The con-

versational style of explication certainly facilitates comprehension of equations, at least some of which Turchin appropriately admits to be "intimidating" (p. 100). Beyond thorough quantitative analysis (and indeed "the devil is in details", p. 298), he helpfully includes much strategic counsel on approaches to employ in different situations and points out differences among competing models. Turchin demonstrates how long is the route from posing a question regarding organismic movement to definitive answers for which a rigorous analysis is both biologically meaningful and mathematically sound. Everyone who really wants to come to grips with such questions will find his book most valuable.

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Maintaining Biodiversity in Forest Ecosystems

Edited by M. L. Hunter, Jr. 1999. Cambridge University Press, Cambridge and New York. 698 pp., illus. Cloth U.S. \$100; paper U.S. \$44.95.

In *Maintaining Biodiversity*, Malcom Hunter has gathered a broad range of material into a comprehensive volume about biodiversity in managed forests. The book is divided into four parts: (1) Introduction; (2) The macro approach, managing forest landscapes; (3) The micro approach, managing forest stands; and (4) Synthesis and implementation. These four broad sections contain 19 chapters by 33 authors that systematically cover many issues facing forest managers and researchers. For example, the section dealing with macro approaches has chapters about species composition, dynamic forest mosaics, abiotic factors, edges, fragmentation, riparian forests, and wetlands. The micro approach considerations are decadent woody material, vertical structure, plantations, special species, and genetic diversity. The final section discusses social, economic, and policy perspectives on implementing many of the ideas in the book.

In the second chapter, Seymour and Hunter state the central axiom of ecological forestry, which is also the central idea of *Maintaining Biodiversity*: the manipulation of a forest ecosystem should work within the limits established by natural disturbance patterns prior to extensive human alteration of the landscape. For an edited volume, the book is a coherent, consistent package, that never strays too far from this theme of ecological forestry, and the axiom of natural disturbance. The approach is based on the coarse- and fine-filter concept, where an array of habitats are

maintained (coarse filter) and species of special concern are managed more intensively (fine filter).

At the centre of ecological forestry is biodiversity. In the first chapter, Hunter walks us through the various kinds of diversity: genetic, species, and ecosystem. These are familiar ideas, and Hunter admits that much is gleaned from his previous two texts on the subject. He provides a detailed account of why it is difficult to measure biodiversity, and of the problems inherent in measuring at the wrong scale. Unfortunately for the reader, the problems are many and the solutions offered are few.

The broad perspective taken with *Maintaining Biodiversity* means that there is material to interest a wide-ranging audience. One drawback of this breadth, however, is that some of the topics are treated without much depth. For example, Brokaw and Lent (chapter 11) spend 27 pages discussing vertical structure in managed forests, but less than two total pages is dedicated to the effects of vertical structure on mammals, reptiles, and birds.

In the preface, Hunter states that the book was primarily intended for students of natural-resource management and professional managers. *Maintaining Biodiversity in Forest Ecosystems* certainly is recommended reading for such an audience, and for anyone else interested in the management of forest resources.

JEFF BOWMAN

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Unentangling Ecological Complexity: The Macroscopic Perspective

By Brian A. Maurer. 1999. The University of Chicago Press, Chicago, 251 pp., illus. Cloth U.S. \$50; paper U.S. \$18.

When the far-travelling hero of *A Hitchhiker's Guide to the Galaxy* finally reached his goal it was with intense surprise that he found The Meaning of Life and The Answer to Everything Else were, in fact, amazingly simple. In a way the title of Dr. Maurer's book promises a similar revelation of enlightenment but, alas, this is not to be. The author's purpose is to point the way rather than divulge the answer.

Despite that, Dr. Maurer's basic premise, repeated throughout the book, does have simplicity. It is that conventional ecosystem investigation by intensively studying the individual parts cannot hope to elucidate the large picture. Productive as these studies may be, there are practical limits to the number of interacting parts that can be included, in the same way that a juggler can only manage a certain number of articles before being overwhelmed. More than that, he argues that since time-constrained localized studies are focused on small scale phenomena they are unable to register the amplitude of large scale processes that might be present as controlling factors, or may obscure them because of localized idiosyncracies. This is not to say he dismisses either the need for or the results from detailed community studies but relegates them to an economic role from which appropriate management policies and prescriptions can be derived, important functions in their own right though not the touchstone he is seeking.

In reaching that point the reader will have been conducted through a quick chronological review of ecological thinking from before the time it became a separate science, examining each step forward, considering its strengths and weaknesses, and discussing its applications. Each is found wanting for the author's needs.

Rather than accepting the assumption that community structure can be understood only by understanding the interaction of its various parts, Professor Maurer asks what other kinds of processes operating at larger scales can influence species diversity locally. To produce an answer he enlarges his field to operate

on a geographic basis, even on a continental scale, while at the same time diminishing the multitude of taxa involved by converting them to statistical systems in the same way that a gas can be most conveniently studied as a mass rather than by examining each component molecule. It is at this point that a certain amount of faith enters the exercise. There is no practical way of manipulating his continental-scale patterns to prove or disprove a given thesis therefore a practitioner is almost bound to accept it at face value.

Development of new approaches to old problems takes time to mature so it is not surprising that the number of pages given over to large scale ecological patterns is far fewer than those dismissing local community ecology. As examples of the former Dr. Maurer points to concentrations in population density across a geographic range, and the relationship between a range and body size of a species, and looks to such openings as the mapping of asymmetry in distribution of competing species within their range, and the mix of species in varying habitat types as possibly fruitful fields of search. It is when the suggestion extends to rates of speciation and extinction that a feeling grows that we may have left ecology, pure and simple, and crossed into something else.

As a professor of zoology, Dr. Maurer argues his case concisely. In this book he is, however, addressing theoretical ecologists rather than the general public. A knowledge of statistical procedures is a definite advantage. In a world where answers to global problems usually run counter to economic and political imperatives, there is no denying the need for incontrovertible data based on large-scale studies for the guidance of policy-makers, though whether there is yet time for such studies to be long-term as well as large-scale is another matter. In this light theoretical advances in ecology should be encouraged even if not all may prove in time to be on the main evolutionary line of this science. Certainly macroscopic ecology offers an intriguing new perspective.

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MISCELLANEOUS

Servants of Nature, a History of Scientific Institutions, Enterprises, and Sensibilities

By Lewis Pyenson and Susan Sheets-Pyenson. W. W. Norton & Company, New York. 496 pp. Can. \$46.99.

Servants of Nature, a historical examination of science and the mechanisms to which it was seeded, grown, and flourished, is by no means definitive, nor is it meant to be. What it does, however, by showing specific regional examples, from South America, the Mediterranean, to Europe and North America, is the diversity of which science has been supported. With these examples, which also cross much of recorded history, we see how the modern realm of science functions in society of today.

The first section concerns institutions. The emergence of universities, their avoidance of "prosaic concerns", in that "they teach what people want to learn and that they give voice to what people prefer to hear" (page 47), and the emergence of the popular appeal of institutional research in providing prestige. With this flourishing of questioning minds, the dissemination of information became more of a practical concern and thus formal and informal societies emerged. With little surprise, politics, internal and external were soon to overshadow any altruistic or pseudo-altruistic desires the founders of these organizations may have had. Because of this, the rate of intellectual expansion, often determined by the political will of the day, deterred the various countries scientific growth. Whereas "Science flourished in Britain during the last half of the seventeenth century . . .", the authors record, "France on the other hand, failed to emerge as a centre of scientific excellence. . . ." (page 87), at least in part due to its own political confusion.

After witnessing the emergence of astronomy, particularity that with telescopes, the authors then focus on museums, gardens, and zoos. The former "served two distinct audiences simultaneously: a few scholars and the public at large." A dichotomy that is in some ways still debated today with many of the major museums radically shifting their mandates to

favor one instead of the other. Some of this may be familiar to the reader of Sheets-Pyenson's earlier work *Cathedrals of Science* (McGill-Queens University Press, 1988) which looked at very specific, geographically distant natural history "movements," and their evolution.

The latter half of *Servants of Nature* wanders through various themes of measuring, expressing, and utilization of science (specifically its military application), finally ending with digressions in belief systems. There are subsections, many of them, that consider other realms of the scientific endeavor, like that of the participation of women. It wasn't until the early 18th century that women "began actively to pursue the physical and especially mathematical sciences" (page 337). Other readers will find other sections on history of statistics, or early exploration and cartography equally informative. The chapter on "Reading" was also enjoyable. "Science as we know it" the authors command, "was the direct result of the invention of the printing press" (page 215), as the printed scientific word soon would become available to larger segments of the populations, not just the literate elite.

There are multiple lines of inquiry that the authors present, though individually instructive, as a bound collective seem to be disjointedly put together. There is no overall glue holding the pages of thought in place. But, if it is kept in mind that this work was not meant to be definitive, don't expect to close the volume and have a grander ideal of the mechanisms and early upbringing of science as a whole. In a piecemeal fashion, the authors of *Servants of Nature* do expect the reader to have a better appreciation of the various running themes that are apparent within science, the human endeavor.

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Modern Wildlife Painting

By Nicholas Hammond. 1998. Yale University Press, New Haven, Connecticut; co-published with Pica Press, London, England. 240 pp., illus. (146 color). U.S. \$50.

Long before humans developed any form of writing, there was art; and "the beginning of all art was animal art." (Dance 1978). The many cave paintings are proof of this, those in the Lascaux region being at least 30 000 years old. Whatever the reason, Neolithic humans needed to express visually their

experience of the animals around them, especially ones important to their hunting/gathering culture. Dispersing around the world, people continued making wild animal art, often stylizing and integrating animals into religious icons and ceremonies, or as decoration. By the Middle Ages, realistic three-dimensional wildlife art illustrated scientific and educational books. Such work blossomed through the Renaissance and later as explorers found "new

worlds" teeming with an amazing variety of unknown plants and animals. By the 18th C wildlife paintings began to show species in their natural habitats. Since then, especially over the past 50 years, this approach has predominated, and full-time artists have proliferated. But as we evolved from responding and adapting to our environment to become powerful, pervasive manipulators, our relationships with wildlife have changed. Much modern wildlife art portrays species living natural lives independent of human use or mythology. But as Hammond points out, today's career artist still has one constraint, marketability – as vital as was the success of the hunt to our Neolithic ancestors!

Nicholas Hammond writes from broad experience: former editorial director of the Royal Society for the Protection of Birds, editor of *Birds*, European writer for *Wildlife Art* (U.S.A.), and presently, a lecturer and consultant on wildlife art. In this volume he focuses primarily on 20th C European and North American bird and mammal artists. Brief biographies of 92 artists are appended to the main text where most are discussed in some detail, and which is generously illustrated with 146 one-half to full page, quality color plates, and 10 black-and-white ones (as are the originals). Sources are listed, and there is a short index to the artists and illustrations.

However, this is not a coffee-table book – the text moves through an in-depth comparative assessment, and thus differs qualitatively from many current large format art books. Read the Preface to understand the author's objective: "... to show how public interest in wildlife and art are interwoven."; his choice of artists: "Each chapter deals with a separate theme... [but] the work of some artists does not fit conveniently into a particular theme. For this reason some artists are not featured... amongst the work included are many that I admire greatly."; and his philosophy: "Particular favourites tend to be those in which the artists' emotional rapport with their subjects is most clearly expressed... the best wildlife art contains a truth, [but it] may not be the suspect truth of the camera lens. If there is a truth... it has little to do with science and is much more likely to be found in the feelings and observations of the artists...". Art is a highly subjective discipline, and an interpreter's (in this case Hammond's) viewpoint is as important as a scientist's hypothesis. Some ecologists may not side with the author's apparent rejection of science in wildlife art. Nevertheless, Hammond evaluates a variety of artists, from the middle 1800s to the present, whose styles include realistic, impressionistic, stylized, and semi-abstract.

The author achieves his objective concisely in the first chapter. In the majority and most interesting portion of the book, he provides an insightful assessment of each artist's style, biographical anecdotes, artistic and societal context, as well as any influence on other artists. Supplementary notes accompany each plate. The chapter themes are: Bruno Liljefors and the Great Outdoors; Louis Agassiz Fuertes and Wildlife Art in North America; Thorburn, the Romantic Scotsman and his Followers; Working in the Field; Illustrating for Identification; Wildlife and Printmaking; and Painting with a Sense of Place. Some artists will be familiar to Canadians: Chris Bacon, Robert Bateman, Guy Coheleach, Don Eckleberry, Francis Lee Jaques, Bob Kuhn, Fenwick Landsdowne, George McLean, Roger Tory Peterson, Carl Rungius, Peter Scott, George Miksch Sutton, and Terrence Shortt.

Naturalists and ecologists should find this attractive and readable book of great interest. Hammond encourages us to enter the personal world of a diverse sample of career wildlife artists. Field naturalists may be surprised, however, to discover that many wildlife artists have a different mind-set toward their common subject. Even realistic artists who spend long periods outdoors, often see wildlife and its habitat primarily in artistic terms (composition, lighting, local color, "artistic" perspective); and to an extent they must, for a painting is not a literal photograph. Perhaps artists and naturalists could experiment with more personal interaction – workshops where wildlife artists, naturalists, and ecologists spend time *together* in the field comparing notes. As a naturalist/artist myself, I believe that both art and nature can be served without sacrificing "truth", to the enrichment of both practitioners, and of the wider public who, increasingly urban and technetronic, is rapidly losing familiarity with the biosphere where: "Over tens of thousands of years, however, man evolved his social behavior and cultural attributes in wilderness environments." (Dasmann 1968). As in the dawn of human culture, wildlife art today is about communication, and, regardless of style, draws us back to our universal origins.

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Dasmann, Raymond F. 1968. A different kind of country. The Macmillan Co., New York. 276 pages.

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NEW TITLES

Zoology

American insects: a handbook of the insects of America north of Mexico. 1999. By R. H. Arnett, Jr. 2nd edition. St. Lucie Press, Boca Raton, Florida. c960pp., illus. U.S. \$89.95.

The art and science of butterfly photography. 2000. By W. Folsom. Amherst Media (distributed by Fitzhenry and Whiteside, Markham, Ontario). 120 pp., illus. \$46.95

†**Behaviour and ecology of sea ducks.** 1999. Edited by R. I. Goudie, M. R. Petersen, and G. J. Robertson. Canadian Wildlife Service Occasional Paper No. 100. Environment Canada, Ottawa. 88pp., illus. Free.

***The birder's field notebook.** 1999. By J. Whiting. Lee Valley Tools, Ottawa. 316 pp. \$15.95.

***The birder's life list and master references.** 1999. By J. Whiting. Lee Valley Tools, Ottawa. 541 pp. \$39.95.

Birds of Australia. 2000. By K. Simpson, N. Day, and P. Trusler. Princeton University Press, Princeton. 440 pp., illus. U.S. \$39.50.

Birds of Europe. 2000. By K. Mullarney, L. Svensson, D. Zetterstrom, and P. J. Grant. Princeton University Press, Princeton. 400 pp., illus. Cloth U.S. \$39.50; paper U.S. \$29.95.

***Birds of India.** 2000. By R. Grimmett, C. Inskipp, and T. Inskipp. Princeton University Press, Princeton. 384 pp., illus. U.S. \$29.95.

A dark place in the jungle: science, orangutans, and human nature. 1999. By L. Spalding. Algonquin Books, Chapel Hill, North Carolina. xiv + 269 pp. U.S. \$22.95.

†**Ecology and conservation of grassland birds of the western hemisphere.** 1999. Edited by P. D. Vickery and J. R. Herkert. Proceedings of a conference, Tulsa, Oklahoma, October 1995. Cooper Ornithological Society, Camarillo, California. 299 pp., illus. Cloth U.S. \$39.50; paper U.S. \$25.

The extended organism: the physiology of animal-built structures. 2000. By J. S. Turner. Harvard University Press, Cambridge. 384 pp., illus. U.S. \$47.50.

Grizzly country. 2000. By A. Russell. Lyons Press, New York. 320 pp., illus. U.S. \$16.95; \$25.95 in Canada.

***A guide to the birds of Southeast Asia: Thailand, Peninsular Malaysia, Singapore, Myanmar, Laos, Vietnam, Cambodia.** 2000. By C. Robson. Princeton University Press, Princeton. 504 pp., illus. U.S. \$ 59.50.

***Hoofed mammals of British Columbia.** 1999. By D. Shackleton. UBC Press, Vancouver. 268 pp., illus. \$24.95.

Killer whales: the natural history and geneology of *Orcinus orca* in British Columbia and Washington State. 2000. By J. K. B. Ford, G. M. Ellis, and K. C. Balcomb. 2nd edition. UBC Press, Vancouver. 100 pp., illus. \$22.95.

Mammals of Madagascar. 1999. By N. Garbutt. Yale, New Haven. 320pp., illus. U.S. \$37.50.

†**Millions of monarchs, bunches of beetles: how bugs find strength in numbers.** 2000. By G. Waldbauer. Harvard University Press, Cambridge, Massachusetts. 264 pp., illus. U.S. \$24.95.

New England wildlife: habitat, natural history, and distribution. 2000. By R. M. DeGraaf and M. Yamasaki. University Press of New England (Canadian Distributor UBC Press, Vancouver). 560 pp., illus. \$52.95.

Sociobiology: the new synthesis. 2000. By E. O. Wilson. Harvard University Press, Cambridge. 720 pp., illus. Cloth U.S. \$75; paper U.S. \$29.95.

***Tadpoles: the biology of anuran larvae.** 1999. Edited by W. McDiarmid and R. Altig. University Chicago Press, Chicago. xvi + 444 pp., illus. U.S. \$70.

Botany

***Illustrated flora of British Columbia, Volume 4: Dicotyledons (Orobanchaceae through Rubiaceae).** 1999. Edited by G. W. Douglas, D. Meidinger, and J. Pojar. B. C. Ministry of Environment, Lands, and Parks, Victoria. 427 pp., illus.

†**Trees: their natural history.** 2000. By P. Thomas. Cambridge University Press, New York. ix + 286; illus. Cloth U.S. \$64.95; paper U.S. \$24.95.

Environment

†**Biodiversity and democracy: rethinking society and nature.** 2000. By P. M. Wood. UBC Press, Vancouver. 288 pp. \$75.

†**Biological diversity: the oldest human heritage.** 1999. By E. O. Wilson. New York State Museum, Albany. ix + 58 pp., illus. U.S. \$4.50.

Blue mountains far away: journey into the American wilderness. 2000. By G. McNamee. Lyons Press, New York. 192 pp. U.S. \$22.95; \$34.95 in Canada.

†**Cliff ecology: pattern and process in cliff ecosystems.** 2000. By D. W. Larsen, U. Matthes, and P. E. Kelly. Cambridge University Press, New York. xvii + 340 pp illus. U.S. \$69.95.

†**The desert: further studies in natural appearances.** 1999. By J. C. Van Dyke. Reissue of 1901 edition. Johns Hopkins University Press, Baltimore. lxiii + 240 pp. U.S. \$16.95.

Ecological diversity in sustainable development: the vital and forgotten dimension. 1999. By C. Maser. St. Lucie Press, Boca Raton, Florida. 432 pp. U.S. \$39.95.

Ecologically based municipal land use planning. 1999. By W. B. Honachefsky. Lewis Publishers, Boca Raton, Florida. c300 pp. U.S. \$69.95.

†**Ecology of a managed terrestrial landscape: patterns and processes of forest landscapes in Ontario.** 2000.

Edited by A. Perera, D. Euler, and I. Thompson. UBC Press, Vancouver. 532 pp., illus. \$95.

Ecological classification of Saskatchewan's mid-boreal ecoregions using resource maps and aerial photographs. 1999. By J. D. Beckingham, V. A. Futoransky, and J. G. W. Corns. UBC Press, Vancouver. 83 pp., illus. \$19.95.

The encyclopedia of the environment. 1999. Edited by S. R. Kellert and M. Black. 160 pp., illus. U.S. \$39.

†**Fatal consumption: rethinking sustainable development.** 2000. Edited by R. Woollard and A. Ostry. UBC Press, Vancouver. 296 pp., illus. \$75.

†**The friendship of nature: a New England chronicle of birds and flowers.** 1999. By M. O. Wright. Reissue of 1900 book edited by D. J. Philipon. Johns Hopkins University Press, Baltimore. 172 pp., illus. U.S. \$16.95.

The hidden forest: the biography of an ecosystem. 1999. By J. R. Luoma. Henry Holt, New York. x + 228 pp. U.S. \$22.

Public policies for environmental protection. 2000. Edited by P. R. Portney and R. N. Stavins. 2nd edition. Resources for the Future Press, Washington. 308 pp. U.S. \$29.95.

Summers with the bears: six seasons in the Minnesota woods. 1999. By J. Becklund. Hyperion, New York. 179 pp., illus. U.S. \$21.

The triple helix: gene, organism, and environment. 2000. By R. Lewontin. Harvard University Press, Cambridge. 192 pp., illus. U.S. \$22.95.

Women and nature: saving the wild west. 1999. By G. Riley. University of Nebraska, Lincoln. xvii + 279., illus. Cloth U.S. \$60; paper U.S. \$24.95.

Miscellaneous

***The amber forest: a reconstruction of a vanished world.** 1999. By G. O. Poinar and R. Poinar. Princeton University Press, Princeton. xviii + 239 pp., illus. U.S. \$29.95.

†**Driftwood valley: a woman naturalist in the northern wilderness.** 1999. By T. C. Stanwell-Fletcher. Oregon State University Press, Corvallis. 352 pp., illus. U.S. \$17.95. Reprint of 1946 edition.

†**The essential Aldo Leopold: quotations and commentaries.** 1999. Edited by C. D. Meine and R. L. Knight. University of Wisconsin Press, Madison. xxii + 362 pp., illus. U.S. \$27.95.

***Extinctions in near time: causes, contexts, and consequences.** 1999. Edited by R. D. E. MacPhee. Kluwer Academic/Plenum Publications, Norwell, Massachusetts. xvi + 394 pp., illus. U.S. \$130.

***Minutes of meetings, 1950 to 1955 of the McIlwraith Ornithological Club, London, Ontario, Canada.** 2000. By W. W. Judd. Phelps Publishing, London. 119 pp. \$10.

Professional secrets of nature photography. 2000. By J.

Holmes. Amherst Media (distributed by Fitzhenry and Whiteside, Markham). 120 pp., illus. \$46.95.

***Three views on creation and evolution.** 1999. Edited by J. P. Moreland and J. M. Reynolds. Zondervan Publishing House, Grand Rapids, Michigan. 296 pp. U.S. \$17.99; \$25.99 in Canada.

Books for Young Naturalists

Biomes of the world. 1999. By M. Allaby. Grolier, Danbury, Connecticut. 9 volume set, 64 pp., illus. each. U.S. \$249 for set.

Critters for kids: a North American wildlife activity book. 1999. By T. Hunter. Fitzhenry and Whiteside, Markham, Ontario. 80 pp., illus. \$8.95.

Exploding ants: amazing facts about how animals adapt. 1999. By J. Settel. Atheneum, New York. 40 pp., illus. U.S. \$16.

A freshwater pond. 1999. By A. Hibbert. Crabtree, New York. 32 pp., illus. Cloth U.S. \$15.96; paper U.S. \$8.06.

Life without light: a journey to earth's dark ecosystems. 1999. By M. Stewart. Watts, Danbury, Connecticut. 128 pp., illus. U.S. \$24.

My favorite tree: terrific trees of North America. 1999. By D. Iverson. 64 pp., illus. Cloth U.S. \$ 19.95; paper U.S. \$9.95.

A rain forest tree. 1999. By L. Kite. Crabtree, New York. 32 pp., illus. Cloth U.S. \$15.96; paper U.S. \$8.06.

Rivers and streams. 1999. By P. A. F. Martin. Watts, Danbury, Connecticut. 143 pp., illus. U.S. \$23.

A Saguaro cactus. 1999. By J. Green. Crabtree, New York. 32 pp., illus. Cloth U.S. \$19.95; paper U.S. \$8.06.

Science fair success with plants. 1999. By P. J. Perry. Enslow, Springfield, New Jersey. 104 pp., illus. U.S. \$19.95.

A tidal pool. 1999. By P. Steele. Crabtree, New York. 32 pp., illus. Cloth U.S. \$15.96; paper U.S. \$8.06.

A whale's tale from the Supper Sea. 1999. By C. J. and B. Rea. Bas Relief, Glenshaw, Pennsylvania. 32 pp., illus. U.S. \$10.95.

Wildlife winners: the peregrin falcon – endangered no more. 2000. By M. Priebe. Mindfull Publishing, Norwalk, Connecticut. 32 pp., illus. U.S. \$15.95.

Windows on the wild: biodiversity basics, an educator's guide to exploring the web of life. 1999. By World Wildlife Fund. Acorn Naturalists, Tustin, California. 477 pp., illus. Educator's guide U.S. \$29.95; U.S. \$39.95 (set).

Windows on the wild: biodiversity basics, student book. 1999. By World Wildlife Fund. Acorn Naturalists, Tustin, California. 229 pp., illus. Student book U.S. \$11.95; U.S. \$39.95 (set).

*Assigned for review

†Available for review

Advice for Contributors to *The Canadian Field-Naturalist*

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The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

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Check recent issues (particularly in literature cited) for journal format. Either "British" or "American" spellings are

acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary**, **Webster's New International Dictionary** and **le Grand Larousse Encyclopédique** are the authorities for spelling.

Illustrations

Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

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Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

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Cover: Pre-fledged Common Loon, *Gavia immer* (YI) Silvester Lake, Ontario, with neck bulge of undigested food. See Alvo and Campbell pages 700–702.

The Decline of Freshwater Molluscs in Southern Manitoba

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A survey of freshwater molluscs was conducted in southern Manitoba in 1998 and was compared with a similar survey from 1975–1978. Sites were classified according to main type of human impact: crops, livestock, logging, recreation, mining, hydro and minimal impact. All development categories increased at the expense of minimal impact sites. Frequencies of freshwater mussels and most gastropods declined, and some species recorded in the earlier survey were not found in 1998. Mean species richness of gastropod communities decreased at all site categories. The lowest richness was consistently observed at sites affected by mining and intensive livestock production. Small gastropod species appeared to show the most precipitous declines.

Key Words: freshwater gastropods, mussels, agriculture, mining, hydro, logging, cottages, development, Manitoba.

Aquatic organisms are disappearing worldwide at an alarming rate as pollution and habitat destruction follow agricultural and urban expansion, and natural resource exploitation. Aquatic species are at much greater risk than terrestrial fauna (Williams et al. 1992). Freshwater organisms are particularly vulnerable to extirpation and extinction because of their island biogeography, where populations may quickly become distinct from each other by virtue of isolation, the founder effect and differential selection pressures. Many species and subspecies of freshwater molluscs are found only in a few lakes or drainage systems and have no refuge when development encroaches on their environment. Other, more widespread, species are also suffering reductions as individual water bodies deteriorate in quality and local populations disappear. Such losses affect not only community diversity and stability, but also reduce the genetic base of each species.

Freshwater molluscs are represented by bivalves and gastropods. Most of the available status information deals with unionids (freshwater mussels), primarily because of their commercial value in the production of seed pearls in the cultured pearl industry, which, sadly, has been a major contributing factor in the destruction of these animals. Commercial exploitation, combined with habitat degradation, have resulted in unionids becoming one of the most imperiled groups in North America (Master 1990). While unionids occur worldwide, the greatest number of taxa are found in North America (Williams et al. 1992). However only a quarter of the U.S. mussel taxa were considered stable in 1994 (Neves and

Williams 1994). This decline is expected to become more severe as introduced zebra mussels extend their range (Neves, 1994).

Comparable estimates for gastropods are lacking. Although the Committee on the Status of Endangered Wildlife in Canada lists two western Canadian species as endangered or threatened (COSEWIC 1999), very little information exists on the current status of most aquatic snails.

During 1975–1978, a survey of freshwater molluscs was conducted at 319 sites in Manitoba south of 54° N (Pip 1978, 1985). The objective of the present study was to repeat the survey in order to compare the current species frequencies with data from 20 years previous.

Materials and Methods

The present survey was conducted from late April to September, 1998 at 308 sites in Manitoba south of 54° N. An effort was made to visit as many as possible of the sites that had been sampled in 1975–1978. Where these sites no longer exist or could not be revisited for other reasons, the next nearest accessible sites in the area were sampled. The sampling procedure has been described by Pip (1978, 1985). Both living specimens and beach drift were examined. Living specimens were identified in the field and returned immediately to their habitats; no collections of live material were made in either the previous or the present surveys.

The critical significance level for all statistical tests was $p = 0.05$. The common names are from Clarke (1981).

Results

The sites in both the 1975–1978 and the 1998 surveys were grouped into seven categories according to the main type of human impact apparent at each site: agricultural crops, livestock production, logging, mining, hydroelectric development, cottages/recreational use and minimal impact (with the possible presence of an access road). Each site was also classified as pond (<10 ha), lake (>10 ha), stream (<2 m deep) or river (>2 m deep).

The results (Table 1) showed a substantial change in the human impacts on the sites. While in 1975–1978, 35.7% of the sites could be classified as minimally affected, in 1998 this proportion was only 18.2%. Furthermore, none of the latter were completely unaffected, as even “remote” sites that were far from road access contained human litter. The reduction in the amount of minimally affected sites was made up by corresponding increases in all the other impact categories. The largest gains in land use adjacent to aquatic habitats were conversions to crop cultivation and intensive livestock production, amounting to a combined difference of approximately 10%.

The frequencies of the sites classified according to water body type also changed conspicuously (Table 1). Whereas 41.4% of the sites were ponds in 1975–1978, in 1998 this group constituted only 15.0% of the sites, due to drainage of low-lying lands and infilling. In contrast, the proportion of lakes remained almost unchanged. Because of the loss of ponds, the site distribution frequencies shifted to rivers and streams, which were usually the closest surface waters available for sampling when the origi-

nal sites no longer existed. The greatest numbers of ponds and wetlands in 1975–1978 had been in minimally impacted regions and in agricultural areas; by 1998 these two categories were also responsible for the greatest losses. The reduction of ponds in minimally impacted areas resulted from recreational development and construction in previously uninhabited districts, including provincial parks. Similarly, as development encroached on lakes, the number of unimpacted sites in this category declined, with a corresponding increase in the proportion of sites affected by cottages and recreational activity.

Freshwater mussels were found at fewer sites in 1998 compared to 1975–1978. Because of the small values, Table 2 lists numbers of sites where each species was recorded, rather than frequencies. The three rarest species from the earlier survey were not found in 1998. *Lampsilis radiata siliquioidea* (Fat Mucket) and *Pyganodon grandis* (Common Floater) were the two most common species in both surveys, but they were found at fewer sites in 1998.

Gastropods were also less easily found in 1998. While 95% of sites examined in 1975–1978 yielded at least one species of snail within the allotted search time of one hour, in 1998 snails could be found in only approximately half of the sites within the same search time. At sites where gastropods were found, mean species richness within the search time dropped from 4.4 in 1975–1978 to 2.5 in 1998. The smallest mean species richness was found in sites affected by mining, and intensive livestock production. This finding was consistent for both 1975–1978 and 1998.

TABLE 1. Site distribution grouped according to main impact and water body type for 1975–1978 (A) and 1998 (B).

A. 1975–78 (319 sites)					
	Pond	Lake	River	Stream	Total
Crops	14.1	0.6	0.9	4.1	19.7
Livestock	1.6	-	1.3	0.3	3.2
Logging	0.6	-	0.8	0.3	1.7
Recreation	3.7	24.8	6.3	3.1	37.9
Mining	0.3	0.3	-	-	0.6
Hydro	-	0.9	0.3	-	1.2
Minimal impact	21.0	7.8	1.6	5.3	35.7
Total	41.3	34.4	11.2	13.1	100

B. 1998 (308 sites)					
	Pond	Lake	River	Stream	Total
Crops	4.6	2.3	4.6	14.0	25.5
Livestock	0.3	-	1.6	5.9	7.8
Logging	0.3	-	1.6	1.6	3.5
Recreation	1.6	30.2	6.5	2.3	40.6
Mining	0.6	0.6	0.3	-	1.5
Hydro	-	0.3	2.6	-	2.9
Minimal impact	7.8	3.6	1.6	5.2	18.2
Total	15.2	37.0	18.8	29.0	100

TABLE 2. Number of sites at which freshwater mussels were found during the two surveys.

Species	1975–1978 (312 sites)	1998 (302 sites)
<i>Strophitus undulatus</i> (Squaw-Foot)	5	4
<i>Anodontoides ferussacianus</i> (Cylindrical Floater)	1	NF
<i>Lasmigona complanata</i> (White Heel-Splitter)	3	2
<i>Lasmigona compressa</i> (Brook Lasmigona)	1	NF
<i>Lasmigona costata</i> (Fluted Shell)	1	NF
<i>Pyganodon</i> (= <i>Anodonta</i>) <i>grandis</i> (Common Floater)	17	6
<i>Quadrula quadrula</i> (Maple-Leaf)	4	2
<i>Lampsilis radiata siliquoidea</i> (Fat Mucket)	16	9
<i>Lampsilis ventricosa</i> (Pocket-Book)	3	2
<i>Proptera alata</i> (Pink Heel-Splitter)	3	2
<i>Ligumia recta</i> (Black Sand-Shell)	4	2
<i>Fusconaia flava</i> (Pig-Toe)	5	2
<i>Amblema plicata</i> (Three-Ridge)	3	1

While reduction in mean species richness was found in all categories of impact, the greatest change, however, was observed for sites affected by logging, and flooding due to hydro development. Although richness also decreased at mining and livestock sites, the difference was smaller because the initial values for 1975–1978 were already low.

With respect to water body type, ANOVA revealed that richness reductions were greatest in rivers and streams, while lakes maintained significantly greater richness ($F = 3.57$, $p = 0.015$), and were therefore the least affected. Multivariate ANOVA with richness as the dependent variable showed that the effects of impact and water body type were independent of each other in both the earlier and the later surveys. Thus all impact types were distributed equally among the four water body types in the overall sampling distribution.

Several species that had been found in 1975–1978 were not found in 1998. Frequencies of occurrence, as a proportion of sites where molluscs were found (Table 3), decreased in the majority of cases. Since molluscs were found at fewer sites in 1998, the overall abundance was in fact reduced for most species. *Lymnaea stagnalis* (Great Pond Snail), *Physa gyrina* (Tadpole Snail), *Helisoma trivolvis* (Larger Eastern Ramshorn) and *Stagnicola elodes* (Common Stagnicola) remained the most common species, but their frequencies were conspicuously reduced. The small planorbids, and particularly *Gyraulus parvus* (Modest Gyraulus) (previously an abundant species) and *Promenetus exacuus* (Keeled Promenetus), showed precipitous declines.

In order to identify which species had been the most affected by human impact, the statistical distribution frequencies of the impact types among the sites sampled (from Table 1) were compared with the occurrence frequencies of each species using correlation analysis. Thus, species whose distributions among the various impacts did not differ significant-

ly from the distributions of the impacts among the sites as a whole were considered to be distributed randomly among the impact groups. The frequencies of occurrence among the various impact groups were also compared between 1975–1978 and 1998 for each species in order to identify changes in distribution.

The results showed that *Lymnaea stagnalis*, *Stagnicola elodes*, *Helisoma trivolvis*, *H. pilsbryi* *infracarinatum* (Greater Carinate Ramshorn), *H. campanulatum* (Bell-mouthed Ramshorn), *Gyraulus deflectus* (Irregular Gyraulus), *Physa gyrina*, *P. jennessi skinneri* (Blunt Prairie Physa), *Amnicola limosa* (Ordinary Spire Snail), *Cincinnatia cincinnatiensis* (Campeloma Spire Snail), *Valvata tricarinata* (Three-keeled Valve Snail) and *V. sincera helicoidea* (Northern Valve Snail) did not differ significantly in their distributions from the overall site impact frequencies, in either 1975–1978 or 1998. These findings suggested that no single impact could be identified as particularly important in the decline of these species.

A number of other species, however, did show statistically significant sensitivities to certain impacts. The distributions of these species are given in Table 4. *Bulinnea megasoma* (Showy Pond Snail) had previously been found at minimally impacted and recreational sites only; by 1998 some of these sites had been logged or cleared. Both *Fossaria modicella* (Modest Fossaria) and *Gyraulus parvus* were no longer found in 1998 at sites affected by intensive livestock production, logging, or flooding by hydro dams. The majority of sites at which *Gyraulus circumstriatus* (Flatly Coiled Gyraulus) was found shifted from minimally impacted sites to sites cleared for agricultural crops. Similarly, *Promenetus exacuus* was now found most frequently at agricultural sites. The distribution of *Helisoma anceps* (Two-ridged Ramshorn) had changed significantly as minimally impacted sites were converted to recreational uses.

TABLE 3. Frequency of species at sites where gastropods were recorded.

Species	1975–1978	1998
<i>Cameloma decisum</i> (Brown Mystery Snail)	0.01	0.01
<i>Valvata sincera helicoidea</i> (Northern Valve Snail)	0.01	NF
<i>Valvata sincera sincera</i> (Ribbed Valve Snail)	<0.01	NF
<i>Valvata tricarinata</i> (Three-keeled Valve Snail)	0.11	0.07
<i>Cincinnatia cincinnatiensis</i> (Cameloma Spire Snail)	0.04	0.01
<i>Marstonia decepta</i> (Baker, 1928)	<0.01	NF
<i>Probythinella lacustris</i> (Flat-ended Spire Snail)	0.02	0.01
<i>Amnicola limosa</i> (Ordinary Spire Snail)	0.15	0.07
<i>Amnicola walkeri</i> (Small Spire Snail)	0.01	NF
<i>Lymnaea stagnalis</i> (Great Pond Snail)	0.64	0.31
<i>Bulinnea megasoma</i> (Showy Pond Snail)	0.05	0.05
<i>Stagnicola elodes</i> (Common Stagnicola)	0.46	0.31
<i>Stagnicola catascopium</i> (Lake Stagnicola)	0.02	0.03
<i>Stagnicola caperata</i> (Blade-ridged Stagnicola)	0.02	0.01
<i>Stagnicola reflexa</i> (Striped Stagnicola)	0.01	NF
<i>Fossaria dalli</i> (Small Pond Snail)	<0.01	NF
<i>Fossaria decampi</i> (Shouldered Northern Fossaria)	0.02	0.01
<i>Fossaria exigua</i> (Graceful Fossaria)	0.02	0.02
<i>Fossaria modicella</i> (Modest Fossaria)	0.14	0.03
<i>Fossaria obrussa</i> (-)	<0.01	NF
<i>Fossaria parva</i> (Amphibious Fossaria)	0.01	0.02
<i>Physa gyrina</i> (Tadpole Snail)	0.63	0.34
<i>Physa jennessi skinneri</i> (Blunt Prairie Physa)	0.09	0.01
<i>Physa integra</i> (Solid Lake Physa)	0.01	0.02
<i>Physa</i> sp. indet.	0.02	<0.01
<i>Aplexa hypnorum</i> (Polished Tadpole Snail)	0.10	0.07
<i>Ferrissia parallela</i> (Flat-sided Lake Limpet)	<0.01	NF
<i>Ferrissia rivularis</i> (Sturdy River Limpet)	0.09	0.01
<i>Helisoma trivolvis</i> (Larger Eastern Ramshorn)	0.48	0.36
<i>Helisoma pilsbryi infracarinatum</i> (Greater Carinate Ramshorn)	0.03	0.03
<i>Helisoma corpulentum</i> (Capacious Manitoba Ramshorn)	0.01	0.04
<i>Helisoma campanulatum</i> (Bell-mouthed Ramshorn)	0.11	0.18
<i>Helisoma anceps anceps</i> (Two-ridged Ramshorn)	0.20	0.08
<i>Helisoma anceps royalense</i> (Lake Superior Ramshorn)	0.01	NF
<i>Planorbula armigera</i> (Say's Toothed Planorbis)	0.17	0.09
<i>Planorbula campestris</i> (Prairie Toothed Planorbis)	0.01	NF
<i>Promenetus exacuus</i> (Keeled Promenetus)	0.15	0.04
<i>Promenetus umbilicatellus</i> (Umbilicate Promenetus)	0.01	NF
<i>Armiger crista</i> (Tiny Nautilus Snail)	0.03	0.01
<i>Gyraulus parvus</i> (Modest Gyraulus)	0.43	0.03
<i>Gyraulus circumstriatus</i> (Flatly Coiled Gyraulus)	0.06	0.02
<i>Gyraulus deflectus</i> (Irregular Gyraulus)	0.09	0.05

Aplexa hypnorum (Polished Tadpole Snail) was the only species whose distribution among the impact types did not correspond with the overall impact distribution for the sites in either 1975–1978 or 1998. This species consistently showed a high frequency in agricultural areas and this pattern remained unchanged.

Discussion

The results showed that a substantial decline in the abundance of freshwater molluscs has occurred in southern Manitoba over the past two decades. A number of species that had been rare in the 1970s were not found in 1998. In some cases, for example *Stagnicola reflexa* (Striped Stagnicola), the water

bodies where this species had occurred no longer existed, and had been either drained or destroyed by construction (including a site in Nopiming Provincial Park).

The serious decline in species richness of gastropod communities observed in this study was due to the disappearance of species with narrower tolerance ranges (e.g., Pip 1988). Thus species identified in the latter study as tolerant of wide inorganic chemical ranges, for example *Lymnaea stagnalis*, *Stagnicola elodes* (= *palustris*), *Helisoma trivolvis* and *Physa gyrina*, were the least affected. Although these species remained unchanged as the four most frequent species, the numbers of sites at which they were found was nonetheless reduced.

TABLE 4. Percent distributions of species that showed significantly nonrandom frequencies with respect to impact type.

Species		Crops	Livestock	Logging	Recreation	Mining	Hydro	Minimal impact
<i>Bulinnea megasoma</i>	1975–1978	-	-	-	30.8	-	-	69.2
	1998	16.7	-	33.4	16.7	-	-	33.4
<i>Fossaria modicella</i>	1975–1978	26.2	2.4	4.8	31.0	-	2.4	33.3
	1998	50.0	-	-	50.0	-	-	-
<i>Helisoma anceps anceps</i>	1975–1978	3.1	-	-	43.8	-	-	53.1
	1998	10.0	-	-	80.0	-	-	10.0
<i>Gyraulus parvus</i>	1975–1978	25.4	3.2	1.6	32.5	-	1.6	35.7
	1998	50.0	-	-	50.0	-	-	-
<i>Gyraulus circumstriatus</i>	1975–1978	30.0	-	5.0	20.0	-	-	45.0
	1998	66.7	-	-	33.3	-	-	-
<i>Promenetus exacuus</i>	1975–1978	29.3	2.4	-	39.0	-	-	29.3
	1998	75.0	-	-	25.0	-	-	-
<i>Aplexa hypnorum</i>	1975–1978	35.7	7.1	7.1	14.3	-	-	-
	1998	71.4	14.3	-	14.3	-	-	-

More perplexing was the dramatic decline of smaller species, even those considered (Pip 1988) to have broad tolerance ranges, for example *Gyraulus parvus*, *Fossaria modicella*, *Armiger crista*, *Planorbula armigera*, and *Promenetus exacuus*. The Modest Gyraulus (*G. parvus*) was the fifth most frequent species in 1975–1978; by 1998 it had become difficult to find. One possible factor contributing to the stress experienced by smaller species may be related to their narrower food bases. Pip (1988) pointed out that, while larger species can utilize a wider choice of food materials, smaller species feed primarily on periphyton. Since the composition and nutritional quality of periphyton are influenced by water chemistry and availability of light (e.g., Eminson and Moss 1980), small gastropods may be selected against disproportionately in environments that are turbid or contaminated by chemical runoff.

While in this study the impact types were distributed equally among all four water body types, streams, rivers and ponds showed greater reductions in species richness than lakes, which consistently showed the highest species richness (Pip 1987). Smaller water bodies are less able to withstand disruption, while the greater dilution capacity and larger size of lakes may allow more opportunity for internal redistribution within a given water body.

The changes in mussel frequency observed in this study parallel other reports of mussel declines in the U.S. and Canada (Williams et al. 1992). The latter workers listed two of the species found in Manitoba, *Lampsilis ventricosa* (Pocket-Book) and *Ligumia recta* (Black Sand-Shell), as cause for special concern in North America. Even though factors that have been significant elsewhere, such as population explosion of the nonindigenous Zebra Mussel and Asian Clam, have not yet affected Manitoba, diminished mussel frequencies and abundance were

noticeable in this study. Apparent causes included habitat disturbance, increased siltation, water level fluctuation due to dams, and, in the case of the Assiniboine River, to commercial harvesting and poaching (Pip 1995). Increasing levels of contaminants such as heavy metals may affect longevity and reproduction through significant accumulation in vital organs of mussels (Pip 1995).

A number of factors appear to be contributing towards the degradation of freshwater habitats in Manitoba. The southcentral portion of the province supports intensive agriculture. In the present study, this factor was the single greatest cause of increased pressure on freshwater habitats. Drainage of wetlands on private and municipal land has resulted in a substantial loss of small lentic habitats. The recent (and continuing) proliferation of hog farming in the province contributes increased ammonia and phosphorus loads, enrichment with organic matter, high turbidity and oxygen depletion when the waste drains from manure-laden fields or leaks from lagoons into local ditches and waterways. During the 1998 survey, some streams in the vicinity of such operations had a terrible stench and appeared entirely barren of macrofauna. Mussels and gilled gastropods can no longer survive in such environments because of reduced oxygen levels that impact them either directly, or through effects on their food or the mussels' fish hosts (e.g., Clarke 1981). Other consequences of agriculture have been the increasing amounts and longer application seasons for chemical fertilizers and pesticides. As individual farms become larger, labor-saving practices such as aerial spraying result in drift that applies toxins directly to water, in addition to leaching and runoff from fields, and rinsing of spraying equipment in ditches and streams. Another factor, seen primarily in southwestern Manitoba, is widespread irrigation, which has contributed to mineralization of surface waters; in this area, many small habitats

have now become too saline to support aquatic communities.

In areas where agriculture does not dominate, logging degrades stream habitats as erosion raises turbidity levels, aquatic systems are inundated with organic matter and water temperatures of unshaded streams increase. Logging has intruded into all treed areas of the province, including provincial parks.

Cottage and recreational areas have been affected by eutrophication and disturbance from motor boats and personal watercraft, as well as the effects of clearing, construction and maintenance of roads, rights-of-way and private properties, and contamination from leaching, spills and dumping of waste. Often development is too dense for the size of the water body. For example in Nopiming Provincial Park on the Precambrian Shield in eastern Manitoba, as new lakes are opened up for development, this is followed by noxious algal blooms at previously oligotrophic sites in as little as five years (Pip, unpublished data). The 1998 survey found that copper sulphate is still widely used in recreational areas to control unmanageable blooms, including in Lake Winnipeg and some provincial parks.

Nutrient enrichment in itself, however, is important only for individual species that have narrow chemical tolerance ranges (Pip 1988), but this factor cannot account for the general reductions in species richness of gastropod communities, as Pip (1987) has shown that richness in the study area is positively correlated with increasing trophic state. Thus other factors in developed areas, such as disturbance, chemical contamination and oxygen depletion may be of greater importance.

Yet other impacts in the study area include mine drainage from tailings, toxic process water and mineshaft brines. Water level fluctuations caused by hydroelectric installations, diversions, and reservoirs prevent establishment of stable benthic communities and render such environments unproductive. Widespread stocking of water bodies with destructive fish such as trout and carp may imperil molluscs or their food sources. Seepage from garbage dumps and underground fuel storage tanks constitute numerous local point sources of pollution throughout the province.

Aquatic organisms inhabit confined spaces and cannot move away from a deteriorating habitat as easily as their terrestrial counterparts. Species with limited ranges and specific habitat requirements may have no reserve populations elsewhere. At the same time, more abundant species are affected as well, as

each loss of an individual population decreases the genetic base of the species. While smaller aquatic habitats have very little ability to withstand environmental insult, the larger water bodies in southern Manitoba, such as Lakes Winnipeg, Manitoba and Dauphin, have also become noticeably affected during the last two decades as evidenced in more severe algal blooms, declining commercial fish catches and increased fish kills.

The large number of factors that are operating, combined with the magnitude of the environmental damage that has already occurred, present a bleak outlook for the future of freshwater aquatic mollusc communities in Manitoba.

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Historical Wildlife Observations in the Canadian Rockies: Implications for Ecological Integrity

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American Elk (*Cervus elaphus*) are now the most abundant large mammal in the Canadian Rockies and they dominate many plant and animal communities. To determine if present populations are reflective of past conditions, or if they have changed due to European influences, we systematically recorded all observations of ungulates and other large mammals found in first-person historical accounts of exploration in the Canadian Rockies from 1792 to 1873. Those data were then tabulated for the Alberta Foothills, the main Rocky Mountains, and the Columbia Valley in three ways, game seen, game sign encountered or referenced, and game shot. In addition, we listed the number of occasions on which Native Americans were mentioned, as well as references to a lack of food or a lack of game. Between 1792 and 1872, 26 expeditions spent a total of 369 days traveling on foot or horseback in the main Canadian Rockies, yet they observed American Elk only 12 times or once every 31 party-days. Other species, such as Bighorn Sheep (*Ovis canadensis*) with 69 sightings, were observed more frequently, but there is no evidence in first-person accounts that game was historically abundant, or that ca. 1790–1880 ungulate populations were resource (food) limited, as is presently the case. Instead, we suggest that ungulate numbers were once kept at low levels by the combined action of carnivore predation and native hunting. If we measure present ecological integrity by the state and process of the ecosystem that existed before European arrival, as others have proposed, then much of the Canadian Rockies today lack ecological integrity.

Key Words: Ecological integrity, historical conditions, Banff National Park, Canadian Rockies, American Elk, *Cervus elaphus*, Bison, *Bison bison*, native people.

According to legislative directives, Canada is to manage her national parks “so as to leave them unimpaired for ... future generations [and] ... ecological integrity ... of natural resources shall be [given] first priority” (Woodley 1993). To comply with these legal mandates, Parks Canada implemented ecosystem-based management and began a study of the states and processes that structured the Canadian Rockies Ecosystem over the last several thousand years. For as Aldo Leopold noted, “if we are serious about restoring [or maintaining] ecosystem health and ecological integrity, then we must know what the land was like to begin with” (Covington and Moore 1994: 45).

Aspen (*Populus tremuloides*), American Elk (hereafter “Elk”) (*Cervus elaphus*), Wolves (*Canis lupus*), fire, and humans were selected as key indicators because they affect both ecosystem structure and function, and because they represent the species and processes most susceptible to change during the period of European influence (Woodley 1993; Woodley et al. 1993). Parks Canada then developed a simplified model linking these elements in the Canadian Rockies (Kay and White 1995). The species and linkages in the model all have value as indicators of ecological integrity (Kay 1991a, 1991b; Woodley and Theberge 1992), and are understood, at least to some degree, from

previous research and monitoring (White et al. 1994, 1998).

Elk are now the most abundant ungulate in the Canadian Rockies (Huggard 1993), but are these populations reflective of past conditions or have they changed due to European influences? What were the historical and pre-Columbian distribution and abundances of Elk and other ungulates in the Canadian Rockies? Were Elk as abundant in the past as they are today?

To address these questions, we analyzed first-person historical accounts of initial exploration. We also conducted studies on faunal remains unearthed from archaeological sites, aspen ecology, fire history — including aboriginal burning, vegetation change using repeat photographs, and Native American hunting (Kay 1994, 1995a, 1997b, 1997c, 1998; Kay et al. 1994*; Kay and White 1995; White et al. 1998). Here, we report the results of our historical analyses.

Methods and Study Area

Many people have used selected quotes from historical journals as evidence that certain species of ungulates were especially abundant during the late 1700s and early 1800s (e.g., Byrne 1968; Nelson 1969a, 1969b, 1970; Nelson et al. 1972). With selective quotations, however, there is always a question

of whether or not the authors included only those passages that supported their preconceived hypotheses. To overcome such bias, we systematically recorded all observations of ungulates and other large mammals found in first-person historical accounts of exploration in the Canadian Rockies from 1792 to 1873. This included Elk, Bison (*Bison bison*), deer — both Mule (*Odocoileus hemionus*) and White-tailed (*O. virginianus*), Moose (*Alces alces*), Bighorn Sheep (*Ovis canadensis*), Mountain Goat (*Oreamnos americanus*), Caribou (*Rangifer tarandus*), Grizzly Bear (*Ursus arctos*), Black Bear (*Ursus americanus*), Wolf, and Mountain Lion or Cougar (*Felis concolor*). We then tabulated those data in three ways (Kay 1990, 1995b; Kay and White 1995).

First, game observed. We listed the explorer, the date of his trip, the length of his trip, the size of the party, and the number of occasions on which the observer actually saw large game animals. If he reported seeing one animal, that was recorded as a single observation, and if he reported seeing ≥ 1 animal at one time, that was also recorded as a single observation. If an explorer reported killing ≥ 1 animal of a particular species at one time, that was recorded as one sighting.

Second, game sign encountered or referenced. We listed the number of occasions on which specific animal sign, usually tracks, was seen or referenced. For instance, if explorers said they were going deer hunting, that was recorded as a single reference to deer. If they said they were going deer and Elk hunting, that was recorded as a single reference to each of those species. Included in these counts are any references to hearing specific animals, such as Wolves howling or Mountain Lions screaming, as well as references to Native American artifacts. If explorers, upon meeting Native Americans, noted that those people had specific animal skins, each of those observations was recorded as a single reference to that species. We also listed the number of occasions on which Native Americans were seen or their sign, footprints, trails, and such were referenced. In addition, we included the number of references made by each party to a lack of food or lack of game. Acts such as shooting a horse for food were each considered a single reference to a food shortage.

Third, game killed. We listed the number of ungulates each explorer reported as having killed. In nearly every instance, early travelers recorded the exact number of animals that they shot. At the time, explorers were free to kill any animals that they encountered. In fact, most expeditions were on the constant lookout for game as they were, or at least attempting to, live off the land.

We used only first-person journals penned at the time of the event or edited versions written soon afterwards because later narrative accounts are less accurate (MacLaren 1984, 1985, 1994a, 1994b,

1994c; White 1991: 613–632; Shaw and Lee 1997). Even “the humblest narrative is always more than a chronological series of events” (McCullagh 1987:30). The ideological implications of most narrative historical accounts are “no different from those of the narrative form in fiction” because narratives are always influenced by prevailing cultural myths (Galloway 1991: 454; Cronon 1992; Pratt 1992; Demeritt 1994; Wishart 1997; Kearns 1998). In addition, we used standard techniques developed by historians to gauge the accuracy of all historical journals analyzed during this study (Forman and Russell 1983).

In order to draw comparisons between different environments within the Canadian Rockies, we focused upon three distinct but contiguous geographic regions — the Alberta Foothills, the main Rocky Mountains, and the Columbia Valley or Rocky Mountain Trench. While these divisions are primarily physiographic, each is also strongly identified with different biogeoclimatic zones or ecoregions. As used here, Alberta’s Foothills extend from the prairies on the east to the Front Ranges on the west while the Rocky Mountain region includes the Front Ranges, Main Ranges, and Western Ranges of the mountain belt that form the Canadian Cordillera in Alberta and British Columbia. Four Canadian National Parks are found in the Rocky Mountain Cordillera. Banff (Canada’s oldest, established in 1885), Yoho (established 1886), Kootenay (established 1920), and Jasper (established 1907). The Columbia Valley is bounded on the east by the Main and Western Ranges of the Rocky Mountains and on the west by the Purcell and Selkirk Ranges of British Columbia. The Canoe, Columbia, and Kootenay Rivers drain the Columbia Valley. For each region, we developed three historical wildlife sighting tables for a total of nine tables.

Known first-person records begin in 1792 and include: (1) Peter Fidler (1991) — 1792–1793; (2) David Thompson (1800–1812*) (Coues 1965; Belyea 1994) — 1800–1812; (3) Alexander Henry (Coues 1965) — 1811; (4) Gabriel Franchère (1969) — 1814; (5) George Simpson (Merk 1931) — 1824–1825; (6) David Douglas (1959) — 1827; (7) Edward Ermatinger (1912) — 1828; (8) George Simpson (1841*) — 1841; (9) Henry Warre (1845*) — 1845; (10) James Hector (Spry 1968) — 1858–1859; (11) John Palliser (Spry 1968) — 1858; (12) James Carnegie (Southesk 1969) — 1859; (13) W. B. Cheadle (1971) (Milton and Cheadle 1865) — 1863; and (14) Walter Moberly (1872*, 1873*) — 1871–1873.

A number of journals kept by travelers on the Athabasca Trail (Athabasca Valley and Pass), though, were not used because few wildlife observations and virtually no kills were made by people utilizing this route after 1828. By then, the Athabasca

Trail was well established as the primary trans-mountain trade route and hunters no longer accom-
panied parties to provide food. Instead, fur trade

brigades crossed the range as quickly as possible
between provision stations at Jasper House in the
Athabasca Valley and Boat Encampment on the

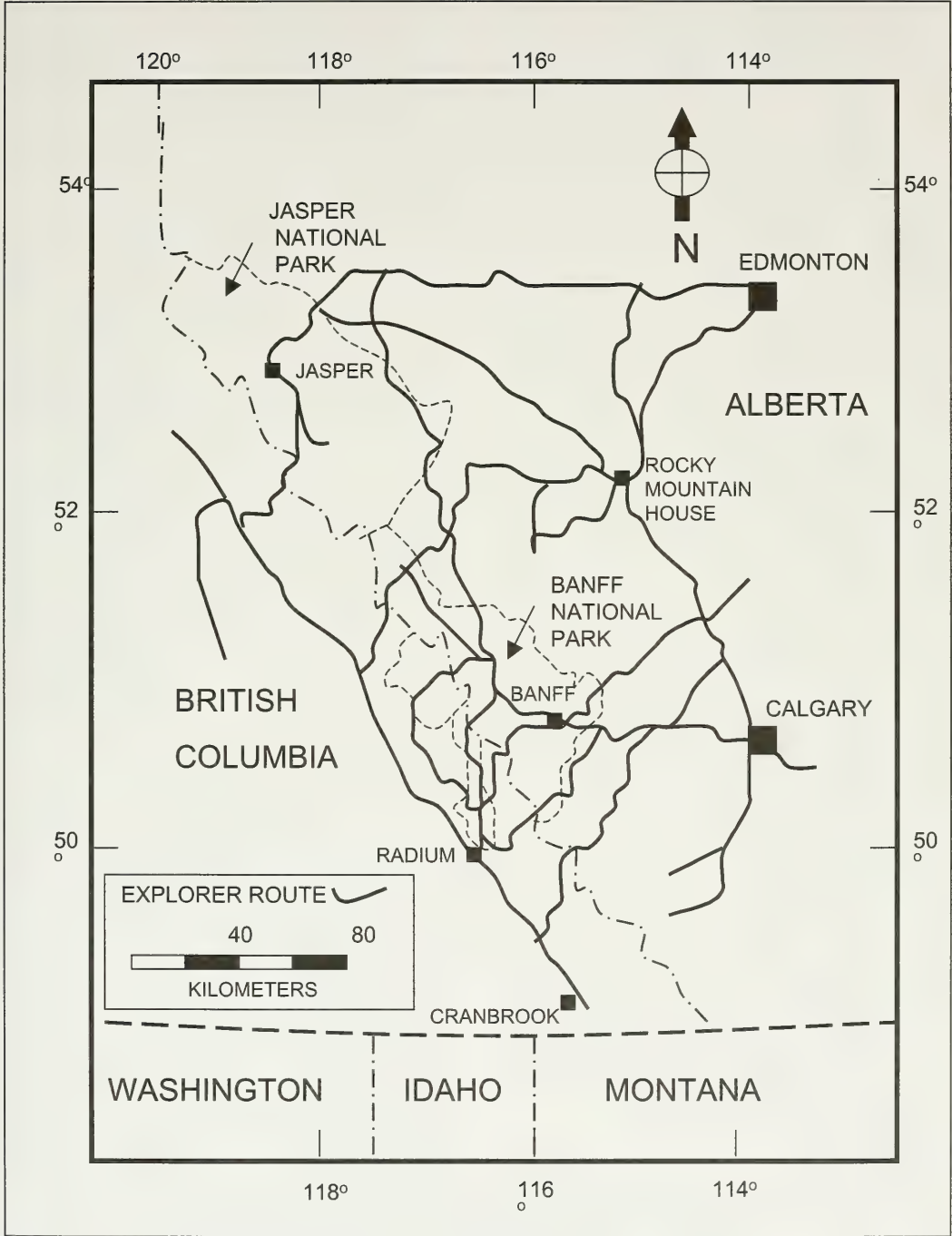


FIGURE 1. Routes of early explorers to the southern Canadian Rockies. Some routes were traveled by more than one expedition. Also shown are Banff, Jasper, Kootenay, and Yoho National Parks, as well as present cities and towns.

Columbia River. In addition, journals kept by residents or visitors at Jasper House (e.g., Michel Klyne 1828–1831, Paul Kane 1847, R. M. Rylatt 1872–1873) (Hudson's Bay Company 1828–1831*; Kane 1968; Rylatt 1991), and Kootenay House (David Thompson 1807–1808) (Coues 1965; Belyea 1994), were not included in our tabular summaries, because static observations differ in nature from those made by mobile parties (Kay et al. 1994*).

Results

Early explorers visited most parts of the Canadian Rockies although their travels were generally confined to major river drainages and established mountain passes (Figure 1). David Thompson first crossed the Canadian Rockies in 1807 by way of the North Saskatchewan River, Howse Pass, and the Blaeberry River. The Peigan, however, objected to Thompson trading with their enemies west of the divide and by 1810, the Peigan had closed the North Saskatchewan to Europeans. This forced David Thompson and the North West Company to find an alternative route further north using the Athabasca River, Whirlpool River, Athabasca Pass, and Wood River to reach the Columbia. The North Saskatchewan route passed through what is now the northern portion of Banff National Park, while the Athabasca Trail traversed today's Jasper National Park. At least two early fur-trade posts were established in what is now Jasper National Park, but none was ever built in Banff, Yoho, or Kootenay.

Only after the Peigan shifted their trade south to American posts on the Missouri River, and then lost their warriors to repeated European-introduced epidemics and other colonial processes, did explorers gain access to the central and southern Canadian Rockies (Smith 1984; Kidd 1986). As a result, the first Europeans known to have traveled Banff's Bow Valley did so only in 1841, and the area comprising Banff, Kootenay, and Yoho National Parks was not fully explored until Dr. James Hector of the Palliser Expedition arrived in 1858. By then, the fur trade was effectively over, and the region's mineral-poor rocks failed to attract the onrush of prospectors that occurred further west in British Columbia. Therefore, relatively few people visited the central Canadian Rockies until the coming of the Canadian Pacific Railroad ca. 1880. Men and supplies for British Columbia's mines arrived from Canada's west coast or from the south via the United States, not across the Canadian Rockies (Patton in press).

Alberta Foothills

Explorers recorded 29 trips in the Alberta Foothills region, traveling a total of 212 days between 1792 and 1863 (Table 1). Bison were the most commonly observed ungulate with 35 sightings. Deer were second at 32+ sightings, while Elk were third at 18. Thus, Bison were reported once

every 6.1 party-days, deer once every 6.6 days, and Elk once every 11.8 days.

Explorers of the Foothills region did not make frequent reference to animal sign (Table 2). This may be because Bison, Elk, and deer were apparently being seen and killed at a far greater frequency than in the Rocky Mountains or Columbia Valley. Nevertheless, sign of Bison and Moose were each recorded on four occasions and Wolf twice. Bear sign of undetermined species was noted twice and Grizzly Bear sign once.

Data on the total number of animals killed by explorers in the Foothills (Table 3) follow the same pattern as wildlife sightings (Table 1). A total of 43 Bison were killed compared to 24+ deer and 19 Elk. Thus, one Bison was killed every 4.9 party-days, deer once every 8.8 days, and Elk once every 11.1 days. Nine Moose, five Bighorn Sheep, one Grizzly, and one Black Bear were also taken.

Rocky Mountains

Between 1792 and 1872, 26 expeditions spent a total of 369 days traveling in the Rocky Mountains. Bighorn Sheep were the most frequently observed large animal with 69 sightings, while Bison were observed on 39 occasions, Moose 27, and Mountain Goat 23 (Table 4). As for American Elk, one of the most numerous and frequently seen ungulates in the Rockies today, only 12 observations are recorded by early explorers. This is a figure equal to the total number of Grizzly and Black bear sightings. So, Bighorn Sheep were reported once every 5.4 party-days, Bison once every 9.5 days, Moose once every 13.4 days, and Elk once every 30.8 days. Other large animal observations included deer 7 times, Caribou 4, Wolf 3, and Cougar 2.

Elk sign was observed on only 11 occasions, nearly equal to Moose at 10 (Table 5). Bison sign was recorded on 19 occasions and Bighorn Sheep on 12. Although Bighorn Sheep were by far the most frequently seen and killed ungulate in the Rocky Mountains, their sign was seldom recorded. As bighorns were usually not tracked like other ungulates, it is understandable why sign of these animals would not be mentioned as frequently as one might otherwise expect.

The most revealing statistics on the relative abundance of ungulates in the Rocky Mountains, however, are found in the record of animals actually killed (Table 6). As previously indicated, Bighorn Sheep lead the tally with 113 animals. Bison were second with 34 kills, followed by Moose at 26, and Mountain Goat at 17. Elk placed a distant fifth with only 9 animals killed. Thus, one Bighorn Sheep was killed every 3.3 party-days, a Bison once every 10.8 days, a Moose once every 14.1 days, and an American Elk once every 46.1 days. Considering that on many of the 369 days these early parties were traveling through the mountains, ≥ 2 hunters were sent out

in search of food, and that much of the hunting took place in montane valleys where Elk are now the most common ungulate, the total of only eight animals killed is revealing and suggests that American Elk were not as common ca. 1800–1870 as they are today. Other animals killed by early explorers in the Rocky Mountains included six deer (both Mule and White-tailed), five Wolves, four Caribou, two Black Bear, and one Grizzly.

Early explorers also made 17 references to a general lack of game while they were in the mountains,

and aside from occasional groups of Bighorn Sheep, large herds of ungulates were not encountered in the Rockies ca. 1800-1870. There certainly is no evidence that there were game animals, and especially Elk, behind every tree, as some have suggested (Byrne 1968; Nelson 1969a, 1969b, 1970; Nelson et al. 1972). Moreover, of the wildlife sightings and kills reported, a large percentage occurred in one area — Kootenay Plains on the North Saskatchewan River. Compared to the rest of the main Canadian Rockies, early explorers reported killing Elk 5.2

TABLE 1. FOOTHILLS: PART I – ANIMALS OBSERVED. Historical evidence relating to the distribution and abundance of ungulates in the Foothills region from 1792 to 1863. Number of occasions on which large animals were reported to have been seen by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Trip Length (days)	Size of party	Number of ungulates and other large animals observed									
				Elk	Elson	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear
1. Peter Fidler 12/30-1/2	1792-93	4	30-50	-	1	-	-	-	-	-	-	-	-
2. David Thompson a. 10/11-10/14	1800 ³	4	8	-	1	-	-	-	-	-	-	-	-
b. 11/29-12/1	1800	4	3+	-	-	-	-	1	-	-	-	-	-
c. 6/6-6/11	1801	6	11	1	4	-	-	1	2	-	-	-	-
d. 5/10-5/16	1807	7	9+	3	4	-	-	-	-	-	-	-	-
e. 6/24-6/26	1808	3	6+	1	2	-	-	-	-	-	-	-	-
f. 10/4-10/20	1808	19	2	4	3	1	-	-	-	-	-	-	-
g. 6/22-6/23	1809	2	8+	1	-	-	-	-	-	-	-	-	-
h. 7/22-7/30	1809	9	6+	1	3	3	-	-	-	-	-	-	-
i. 6/20-6/22	1810	3	8-11	2	1	1	-	1	-	-	-	1	-
j. 10/29-12/29	1810	62	24	2	14	1	-	1	-	-	-	-	-
k. 5/14-5/16	1812	3	4	1	-	-	-	-	-	-	-	-	-
3. Alexander Henry a. 2/3-2/4	1811	2	8	-	-	1	-	-	-	-	-	-	-
b. 2/12-2/13	1811	2	8	-	-	-	-	-	-	-	-	-	-
4. Gabriel Franchère 5/25-5/28	1814	4	10	1	-	-	-	-	1	-	-	-	-
5. George Simpson a. 4/26-4/29	1825	2	12+	1	-	-	-	-	1 ⁴	-	-	-	-
b. 7/31-8/1	1841	2	12+	-	1	-	-	-	-	-	-	-	-
6. David Douglas 5/5-5/7	1827	3	9+	-	-	-	-	-	1	-	-	-	-
7. Edward Ermatinger 9/23-10/1	1828	9	49	-	-	-	-	-	-	-	-	-	-
8. James Hector a. 8/6-8/7	1858	2	5	-	-	1	-	-	-	-	-	-	1
b. 9/28-10/2	1858	5	5	-	-	-	-	5	-	-	-	-	-
c. 12/10-12/14	1858	5	4	-	1	2 ⁵	-	-	-	-	-	-	-
d. 1/21-1/30	1859	10	4	-	-	-	-	-	-	-	-	-	-
e. 2/20-2/25	1859	6	4	-	-	-	-	-	-	-	-	-	-
f. 8/15-8/16	1859	2	9	-	-	1	-	-	-	-	-	-	-
9. John Palliser 8/10-8/17	1858	8	6	1	-	2	-	-	-	-	-	-	-
10. James Carnegie a. 8/25-9/1	1859	7	11	-	-	-	-	-	1	-	-	-	-
b. 10/1-10/5	1859	5	11	-	-	19	-	-	-	-	1	-	-
11. W.B. Chiesle 6/17-6/28	1863	12	6	-	-	-	-	-	1	-	-	-	-
Total	1792-1863	212	Varied	19	35	32+	-	4	8	-	1	-	1

¹See Table 3 for citations.
²Species not reported in original journals.
³Thompson wrote: "Buffalo, Red Deer, Moose & small Deer are also Plenty and Grisdled Bears but too many."
⁴On April 29 Simpson wrote: "Saw about 50 Moose & Red Deer, but time was too valuable to amuse ourselves in hunting..."
⁵On December 11 Hector stated that "The Virginian (white-tailed) deer is very abundant in this district, and we are continually starting them..." and again on December 13 he noted that "we started band after band of deer, just as if we were passing through a deer park. This is the only time I have ever seen game in such plenty in the country, excepting of course buffalo herds."

times more frequently once they reached Kootenay Plains — one Elk killed per 56.2 days in other areas of the mountains versus one Elk killed per 10.7 days on Kootenay Plains. Bison were killed 2.3 times more frequently on Kootenay Plains (12.0 vs.

5.3 days per kill), while Bighorn Sheep were killed 4.2 times more frequently (4.2 vs. 1.0 days per kill).

Jasper House post journals also indicate that ungulates, and especially Elk, were not abundant even

TABLE 2. FOOTHILLS: PART II — ANIMAL SIGN. Historical evidence relating to the distribution and abundance of ungulates in the Foothills region from 1792 to 1863. Number of occasions on which animal sign was reported to have been seen, heard or referenced by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Number of occasions on which animal sign was seen, heard or referenced										Grizzly Bear	Black Bear	Bear ²	Number of occasions on which Natives were seen or sign observed or referenced	Seen	Sign	Reference to lack of game or lack of food.
		Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar								
1. Peter Fidler	1792-93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2. David Thompson	12/30-1/2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a. 10/11-10/14	1800	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-
b. 11/29-12/1	1800	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
c. 6/6-6/11	1801	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
d. 5/10-5/16	1807	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
e. 6/24-6/26	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f. 10/4-10/20	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
g. 6/22-6/23	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
h. 7/22-7/30	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
i. 6/20-6/22	1810	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
j. 10/29-12/29	1810	-	1	-	-	-	-	1	-	-	-	-	-	-	1	-	-	-
k. 5/14-5/16	1812	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Alexander Henry	1811	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
a. 2/3-2/4	1811	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-
b. 2/12-2/13	1811	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4.. Gabriel Franchère	5/25-5/28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. George Simpson	1825	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
a. 4/28-4/29	1825	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b. 7/31-8/1	1841	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
6. David Douglas	5/5-5/7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Edward Ermatinger	9/23-10/1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. James Hector	1858	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
a. 8/6-8/7	1858	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-
b. 9/28-10/2	1858	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
c. 12/10-12/14	1858	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d. 1/21-1/30	1859	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	-	-
e. 2/20-2/25	1859	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f. 8/15-8/16	1859	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. John Palliser	8/10-8/17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
10. James Carnegie	a. 8/25-9/1	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	1+	-
b. 10/1-10/5	1859	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-
11. W.B. Cheshire	6/17-6/28	-	-	-	-	-	-	-	-	2	-	-	-	-	2	-	-	-
Total	1792-1863	1	4	-	-	-	-	4	-	2	-	1	-	2	10	6+	-	-

¹See Table 3 for citations.

²Species not reported in original journals.

TABLE 3. FOOTHILLS: PART III – ANIMALS KILLED: Historical evidence relating to the distribution and abundance of ungulates in the Foothills region from 1792 to 1863. Number of ungulates and other large animals reported to have been killed by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer	Date	Number of ungulates and other large animals killed										Bear ¹	Reference
		Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	
1. Peter Fidler 12/30-1/2	1792-93	-	1	-	-	-	-	-	-	-	-	-	Fidler 1991: 42-54
2. David Thompson a. 10/11-10/14	1800	-	1	-	-	-	-	-	-	-	-	-	Thompson 1800
b. 11/29-12/1	1800	-	-	-	-	4	-	-	-	-	-	-	Thompson 1800
c. 6/6-6/11	1801	-	6	-	-	-	3	-	-	-	-	-	Dempsey 1965:3-6
d. 5/10-5/16	1807	2	4	-	-	-	-	-	-	-	-	-	Thompson 1807
e. 6/24-6/26	1808	-	1	-	-	-	-	-	-	-	-	-	Thompson 1808
f. 10/4-10/20	1808	10	8	1	-	-	-	-	-	-	-	-	Thompson 1808
g. 6/22-6/23	1809	1	-	-	-	-	-	-	-	-	-	-	Thompson 1809
h. 7/22-7/30	1809	-	1	2	-	-	-	-	-	-	-	-	Thompson 1809
i. 6/20-6/22	1810	2	1	-	-	-	-	-	-	-	-	-	Thompson 1810
j. 10/29-12/29	1810	3	18	1	-	1	2	-	-	-	1	-	Thompson 1810
k. 5/14-5/16	1812	-	-	-	-	-	-	-	-	-	-	-	Thompson 1812
3. Alexander Henry a. 2/3-2/4	1811	-	-	-	-	-	-	-	-	-	-	-	Coues 1965: 676-678
b. 2/12-2/13	1811	-	-	-	-	-	-	-	-	-	-	-	Coues 1965: 698-699
4. Gabriel Franchère 5/25-5/28	1814	1	-	-	-	-	2	-	-	-	-	-	Franchère 1969: 163-165
5. George Simpson a. 4/28-4/29	1825	-	-	-	-	-	1	-	-	-	-	-	Merk 1931:148
b. 7/31-8/1	1841	-	-	-	-	-	-	-	-	-	-	-	Simpson 1841
6. David Douglas 5/5-5/7	1827	-	-	-	-	-	-	-	-	-	-	-	Douglas 1959: 262-263
7. Edward Ermatinger 9/23-10/1	1828	-	-	-	-	-	-	-	-	-	-	-	Ermatinger 1912: 106-108
8. James Hector a. 8/6-8/7	1858	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 287-289
b. 9/28-10/2	1858	-	-	-	-	-	-	-	-	-	-	1	Spry 1968: 336-337
c. 12/10-12/14	1858	2	1 ²	-	-	-	-	-	-	-	-	-	Spry 1968: 354-357
d. 1/21-1/30	1859	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 334-368
e. 2/20-2/25	1859	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 382-384
f. 8/15-8/16	1859	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 433-435
9. John Palliser 8/10-8/17	1858	-	-	2	-	-	-	-	-	-	-	-	Spry 1968: 264-268
10. James Carnegie a. 8/25-9/1	1859	-	-	-	-	-	1	-	-	-	-	-	Southesk 1969: 175-190
b. 10/1-10/5	1859	-	-	17	-	-	-	-	-	-	-	-	Southesk 1969: 254-264
11. W.B. Cheedle 6/17-6/28	1863	-	-	-	-	-	-	-	-	-	-	-	Cheedle 1971: 153-160
Total	1792-1863	19	43	24+	-	5	9	-	-	-	1	1	-

¹Species not reported in original journals.

²Hector stated that “Virginian deer is very abundant in this district...” and “...there is one killed nearly every day by some of us.”

during winter as reports of people starving were common (Hudson's Bay company 1828-1831*; Kane 1968; Rylatt 1991). Moreover, recent excavations at Jasper House (Pickard and D'Amour 1987*) permit comparison of historical accounts with

unearthed faunal remains. Not only were Elk seldom reported in first-person documents, but the species ranked third in recovered faunal remains behind Bighorn Sheep and Moose, which together accounted for nearly 80% of the total.

TABLE 4. ROCKY MOUNTAINS: PART I - ANIMALS OBSERVED. Historical evidence relating to the distribution and abundance of ungulates in the Rocky Mountain region from 1792 to 1863. Number of occasions on which large animals were reported to have been seen by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Trip Length (days)	Size of party	Number of ungulates and other large animals observed											
				Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Bear ²
1. Peter Fidler	1792-93	1	43+	-	-	-	-	-	-	-	-	-	-	-	-
2. David Thompson															
a. 6/12-6/14	1801	3	11	-	1	-	-	1 ³	-	-	-	-	-	-	-
b. 5/17-6/30	1807	45	9+	2	13	-	1	3	-	-	-	-	-	2	-
c. 6/18-6/23	1808	5	6+	2	-	-	-	2	-	-	-	-	-	1	-
d. 10/21-10/31	1808	9	6+	2	5	-	2	1	-	-	-	-	-	-	-
e. 6/10-6/21	1809	12	6+	2	2	-	3	3	-	-	-	-	-	-	-
f. 7/31-8/13	1809	11	6+	-	3	-	-	-	-	-	-	-	-	-	-
g. 6/17-6-19	1810	3	8-11	-	1	-	-	-	-	-	-	-	-	-	-
h. 12/30-1/19	1810-11	21	13	-	3	-	-	2	3	-	-	-	-	-	-
i. 5/6-5/13	1812	8	3	-	1	-	-	2	-	-	-	-	-	-	-
3. Alexander Henry															
2/5-2/12	1811	8	8	-	8	-	2	10	-	-	2	-	-	-	-
4. Gabriel Franchère															
5/12-5/24	1814	13	10	-	1	-	-	-	-	-	-	-	-	-	-
5. George Simpson															
a. 10/10-10/19	1824	10	12	-	-	-	1	1	-	-	-	-	-	-	-
b. 4/22-4/28	1825	7	12+	-	-	-	-	-	-	-	-	-	-	-	-
c. 8/2-8/7	1841	6	12+	1	-	-	1	1	-	-	-	-	-	-	-
6. David Douglas															
4/28-5/5	1827	8	9	-	-	-	-	2	-	-	-	-	-	-	-
7. Edward Ermatinger															
9/23-10/1	1828	10	49	-	-	-	-	-	2	-	-	-	1	-	-
8. Henry J. Warre															
7/24-7/30	1845	7	16	-	1	-	1	-	1	-	-	-	1	-	-
9. James Hector															
a. 8/11-9/27	1858	48	5	3	-	2	4	10	14	-	-	2	-	1	1
b. 1/31-2/19	1859	20	4	-	-	-	-	1	4	-	1	-	-	-	-
c. 8/17-9/16	1859	31	9	1	-	3	3	6	5	-	-	-	-	1	-
10. John Palliser															
8/18-8/28	1858	11	1	1	-	2	1	-	-	-	-	-	1	-	-
11. James Carnegie															
9/2-9/30	1859	29	11	-	-	-	5	16	2	-	-	-	2	-	-
12. W.B. Cheadle															
6/29-7/17	1863	19	6	-	-	-	1	2	-	-	-	-	-	-	-
13. Walter Moberly															
a. 10/10-10/23	1871	14	4+	-	-	-	-	-	-	-	-	-	-	-	-
b. 8/28-9/6	1872	10	4	-	-	-	-	-	-	-	3	-	1	-	-
Total	1792-1872	369	Varied	12	39	7	23	69	27	4	3	2	6	5	1

¹See Table 6 for citations.

²Species not reported in original journals.

³Thompson referred to sheep as goats, so it is likely that "three Mountain Goats" killed were sheep. After 1807, however, he referred to these animals by their correct names.

Columbia Valley or Rocky Mountain Trench

The Columbia Valley recorded the fewest number of expeditions and explorer- days of the three regions analyzed in this study. Our survey uncovered journals of only 11 parties who spent a total of 161 days in the Trench. These journals encompass

a period starting in 1807 and ending in 1859. The large mammal most frequently seen in the Columbia was deer with 14 observations (Table 7). Elk was the second with 7. Thus, deer were reported once every 11.5 days while Elk were seen once every 23 days. The remainder of sightings were

TABLE 5. ROCKY MOUNTAINS; PART II – ANIMAL SIGN. Historical evidence relating to the distribution and abundance of ungulates in the Rocky Mountain region from 1792 to 1863. Number of occasions on which animal sign was reported to have been seen, heard or referenced by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Number of occasions on which animal sign was seen, heard or referenced												Number of occasions on which Natives were seen or sign observed or referenced		Reference to lack of game or lack of food	
	Date	Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Bear ²	Seen		Sign
1. Peter Fidler 12/31-1/1	1792-93	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-
2. David Thompson a. 6/12-6/14	1801	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b. 5/17-6/30	1807	1	1	-	-	-	2	-	-	-	-	-	-	-	1	5
c. 6/18-6/23	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
d. 10/21-10/31	1808	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
e. 6/10-6/21	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
f. 7/31-8/13	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
g. 6/17-6-19	1810	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
h. 12/30-1/19	1810-11	1	3	-	-	1	1	-	-	-	1	-	-	-	-	-
i. 5/6-5/13	1812	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Alexander Henry 2/5-2/12	1811	-	6	-	1	3	-	-	1	-	-	-	-	1	-	1
4. Gabriel Franchère 5/25-5/28	1814	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
5. George Simpson a. 10/10-10/19	1824	-	1	1	1	1	-	-	-	-	-	-	-	-	-	3
b. 4/22-4/28	1825	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
c. 8/2-8/7	1841	1	1	-	2	2	1	-	1	-	-	-	1	-	-	3
6. David Douglas 4/28-5/5	1827	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Edward Ermatinger 9/23-10/1	1828	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Henry J. Warre 7/24-7/30	1845	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
9. James Hector a. 8/11-9/27	1858	3	1	2	2	1	2	-	-	1	-	-	1	1	2	2
b. 1/31-2/19	1859	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1
c. 8/17-9/16	1859	2	1	2	-	-	2	-	-	1	-	-	3	-	-	-
10. John Palliser 8/18-8/28	1858	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-
11. James Carnegie 9/2-9/30	1859	-	-	-	-	-	1	-	-	-	-	-	2	1	-	-
12. W.B. Cheade 6/29-7/17	1863	-	-	-	-	1	-	-	-	-	-	-	-	1	2	-
13. Walter Moberly a. 10/10-10/23	1871	3	2 ⁴	1	-	1	-	2	-	-	1	-	1	-	1	-
b. 8/28-9/6	1872	-	-	-	-	-	-	3	-	-	1	-	-	-	1	-
Total	1792-1872	11	19	6	7	12	10	6	3	2	5	-	8	5	10	17

¹See Table 6 for citations.
²Species not reported in original journals.
³Simpson commented that, after crossing the Miette River, "The country...appears well stocked with animals."
⁴Moberly noted that all bison sign was old: "In bye gone years these animals must have been plentiful here as I saw many of their skulls & innumerable places they had hollowed out in the soft ground to lie in."

divided among Bighorn Sheep 2, Moose 2, Mountain Goat 1, Wolf 1, and Black Bear 1. Tracks and other sign of large animals were also

seldom reported in the Columbia Valley (Table 8). Sign of deer was noted on six occasions: Moose 4, Elk 4, and Bear once. The only Elk sign recorded

TABLE 6. ROCKY MOUNTAINS: PART III - ANIMALS KILLED. Historical evidence relating to the distribution and abundance of ungulates in the Rocky Mountain region from 1792 to 1863. Number of ungulates and other large animals reported to have been killed by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer	Date	Elk	Bison	Deer	Number of ungulates and other large animals killed							Cougar	Gritzy Bear	Black Bear	Reference
					Goat	Bighorn Sheep	Moose	Caribou	Wolf						
1. Peter Fidler	1792-93	-	-	-	-	-	-	-	-	-	-	-	-	-	Fidler 1991: 44-53
2. David Thompson															
a. 6/12-6/14	1801	-	-	-	-	3 ²	-	-	-	-	-	-	-	-	Thompson 1801
b. 5/17-6/30	1807	2	12	-	-	2	-	-	-	-	-	-	-	2	Thompson 1807
c. 6/18-6/23	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	Thompson 1808
d. 10/21-10/31	1808	-	4	-	3	1	-	-	-	-	-	-	-	-	Thompson 1808
e. 6/10-6/21	1809	2	3	-	-	14	-	-	-	-	-	-	-	-	Thompson 1809
f. 7/31-8/13	1809	-	-	-	-	2	-	-	-	-	-	-	-	-	Thompson 1809
g. 6/17-6/19	1810	-	1	-	-	-	-	-	-	-	-	-	-	-	Thompson 1810
h. 12/30-1/19	1810-11	-	3	-	-	3	4	-	-	-	-	-	-	-	Thompson 1810-11
i. 5/6-5/13	1812	-	-	-	-	4	-	-	-	-	-	-	-	-	Thompson 1812
3. Alexander Henry															
2/5-2/12	1811	-	8	-	-	7	-	-	1	-	-	-	-	-	Coues 1965: 679-699
4. Gabriel Franchère															
5/12-5/24	1814	-	-	-	-	-	-	-	-	-	-	-	-	-	Franchère 1969: 158-163
5. George Simpson															
a. 10/10-10/19	1824	-	-	-	2	2	-	-	-	-	-	-	-	-	Merk 1931: 29-36
b. 4/22-4/28	1825	-	-	-	-	-	-	-	-	-	-	-	-	-	Merk 1931: 143-148
c. 8/2-8/7	1841	1	-	-	-	-	-	-	-	-	-	-	-	-	Simpson 1841
6. David Douglas															
4/28-5/5	1827	-	-	-	-	2	-	-	-	-	-	-	-	-	Douglas 1959: 255-262
7. Edward Ermatinger															
10/1-10/10	1828	-	-	-	-	-	3	-	-	-	-	1	-	-	Ermatinger 1912: 108-110
8. Henry J. Warre															
7/24-7/30	1845	-	1	-	-	-	1	-	-	-	-	-	-	-	Warre 1845
9. James Hector															
a. 8/11-9/27	1858	1	-	1	2	20	13	-	-	-	-	-	-	-	Spry 1968: 289-335
b. 1/31-2/19	1859	-	-	-	-	3	-	-	4 ³	-	-	-	-	-	Spry 1968: 368-382
c. 8/17-9/16	1859	1	-	3	6	7	2	-	-	-	-	-	-	-	Spry 1968: 435-453
10. John Palliser															
8/18-8/28	1858	2	-	2	-	-	-	-	-	-	-	-	-	-	Spry 1968: 269-279
11. James Carnegie															
9/2-9/30	1859	-	-	-	2	32	3	-	-	-	-	-	-	-	Southesk 1969: 190-251
12. W.B. Cheadle															
6/29-7/17	1863	6	-	-	2	10	-	-	-	-	-	-	-	-	Cheadle 1971: 160-181
13. Walter Moberly															
a. 10/10-10/23	1871	-	-	-	-	-	-	-	-	-	-	-	-	-	Moberly 1871
b. 8/28-9/6	1872	-	-	-	-	-	-	4	-	-	-	-	-	-	Moberly 1872
Total	1792-1872	9	34	6	17	113	26	4	5	-	-	1	2	-	

¹Species not reported in original journals.
²Thompson referred to sheep as goats the previous autumn, so it is likely that "three Mountain Goats" killed were sheep. After 1807, however, he referred to these animals by their correct names.
³Hector wrote that the Jasper House factor baited and killed four Wolves with strychnine.

after 1811 was by James Hector who passed a pile of antlers on his way south from the mouth of the Blaeberry River in 1859. He suggested antlers had been stacked there for many years and noted that

TABLE 7. COLUMBIA VALLEY: PART 1—ANIMALS OBSERVED. Historical evidence relating to the distribution and abundance of ungulates in the Columbia Valley from 1807 to 1859. Number of occasions on which large animals were reported to have been seen by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Length of trip (days)	Size of party	Number of ungulates and other large animals observed									
				Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear
1. David Thompson													
	a. 7/1-7/19	19	9+	1	-	8	-	-	-	-	-	-	-
	b. 6/5-6/17	13	6+	1	-	1	-	-	-	-	-	-	-
	c. 11/1-11/13	13	6+	-	-	-	-	-	-	-	-	-	-
	d. 4/27-6/9	44	8+	2	-	3	1	-	-	-	1	-	-
	e. 8/14-8/20	7	8+	1	-	1	-	1	-	-	-	-	-
	f. 6/8-6/16	9	8-11+	-	-	-	-	-	-	-	-	-	-
	g. 4/17-5/14	28	4	2	-	1	-	-	-	-	-	-	-
2. George Simpson													
	h. 9/18-9/23	6	8	-	-	-	-	-	2	-	-	-	-
3. Henry J. Warre	8/7-8/9	3	12+	-	-	-	-	-	-	-	-	-	-
4. James Hector													
	7/30-8/1	3	16	-	-	-	-	1	-	-	-	-	-
	9/17-10/2	16	9	-	-	-	-	-	-	-	-	-	1
Total	1807-1859	161	Varied	7	-	14	1	2	2	-	1	-	1

¹See Table 9 for citations.
²Species not reported in original journals.

TABLE 8. COLUMBIA VALLEY: PART II -- ANIMAL SIGN. Historical evidence relating to the distribution and abundance of ungulates in the Columbia Valley from 1807 to 1859. Number of occasions on which animal sign was reported to have been seen, heard or referenced by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Number of occasions on which animal sign was seen, heard or referenced												Number of occasions on which Natives were seen or sign observed or referenced		Reference to lack of game or lack of food
	Date	Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Bear ²		
													Seen	Sign	
1. David Thompson															
a. 7/1-7/19	1807	1	-	2	-	-	-	-	-	-	-	-	2	-	2
b. 6/5-6/17	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	1
c. 11/1-11/13	1808	-	-	1	-	-	-	-	-	-	-	-	-	-	2
d. 4/27-6/9	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	1
e. 8/14-8/20	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	2
f. 6/8-6/16	1810	1	-	1	-	-	-	-	-	-	-	-	1	-	1
g. 4/17-5/14	1811	2	-	-	-	-	-	-	-	-	-	-	1	-	1
h. 9/18-9/23	1811	-	-	-	-	-	3	-	-	-	-	-	-	-	3
2. George Simpson															
8/7-8/9	1841	-	-	-	-	-	-	-	-	-	-	-	1	-	-
3. Henry J. Warre															
7/30-8/1	1845	-	-	1	-	-	1	-	-	-	-	-	1	-	-
4. James Hector															
9/17-10/2	1859	1 ⁴	-	1	-	-	-	-	-	-	-	-	3	1	-
Total	1807-1859	5	-	6	-	-	4	-	-	-	-	-	7	3	9

¹See Table 9 for citations.
²Species not reported in original journals.
³An exploration of the Canoe River following the Rocky Mountain Trench north 50 miles from the Big Bend of the Columbia River. Thompson wrote in his *Narrative* (Glover, page, 324) that "Moose Deer and Beaver were plentiful" in this valley.
⁴Hector indicated that this was old sign, writing that: "Elk or wapiti must at one time have been very numerous in this district, as we saw a great many antlers lying on the ground, and sometimes the Indians had piled them in heaps of 50 or 60 together... We have not seen a single track of elk yet in the valley, and but only a few of the smaller deer."

TABLE 9. COLUMBIA VALLEY: PART III – ANIMALS KILLED. Historical evidence relating to the distribution and abundance of ungulates in the Columbia Valley from 1807 to 1859. Number of ungulates and other large animals reported to have been killed by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer	Date	Number of ungulates and other large animals killed										Grizzly Bear	Black Bear	Bear ¹	Reference
		Elk	Bison	Deer	Goat	Sheep	Bighorn	Moose	Caribou	Wolf	Cougar				
1. David Thompson	1807	1	-	7	-	-	-	-	-	-	-	-	-	-	Thompson 1807
	a. 7/1-7/19														
	b. 6/5-6/17	1	-	1	-	-	-	-	-	-	-	-	-	-	Thompson 1808
	c. 11/1-11/13	1	-	-	-	-	-	-	-	-	-	-	-	-	Thompson 1808
	d. 4/27-6/9	1	-	3	2	-	-	-	-	1	-	-	-	-	Thompson 1809
	e. 8/14-8/20	1	-	1	-	3	-	-	-	-	-	-	-	-	Thompson 1809
	f. 6/8-6/16	-	-	-	-	-	-	-	-	-	-	-	-	-	Thompson 1810
	g. 4/17-5/14	3	-	1	-	-	-	-	-	-	-	-	-	-	White 1950: 139-165
	h. 9/18-9/23	-	-	-	-	-	-	1	-	-	-	-	-	-	Thompson 1811
2. George Simpson	1841	-	-	-	-	-	-	-	-	-	-	-	-	-	Simpson 1841
	8/7-8/9														
3. Henry J. Warre	1845	-	-	-	-	-	-	-	-	-	-	-	-	-	Warre 1845
	7/30-8/1														
4. James Hector	1859	-	-	-	-	-	-	-	-	-	-	-	1	-	Spry 1968: 453-461
	9/17-10/2														
Total	1807-1859	7	-	13	2	3	1	-	-	1	-	-	1	-	

¹Species not reported in original journals.

none were from recent kills. References to a general lack of game were made on nine occasions, a rate which is 21% higher per expedition-day than that recorded in the Rocky Mountains.

Deer were the most frequently killed animal with a total of 13 (Table 9), all taken by David Thompson south of the mouth of the Blaeberry River between 1807 and 1811. Elk kills totaled seven, again all by David Thompson and his men prior to 1812. Thus, a deer was killed once every 12.4 days while an Elk was killed once every 23 days. Other recorded kills include 3 Bighorn Sheep, 2 Mountain Goats, 1 Moose, 1 Wolf, and 1 Black Bear. It should be noted that all Moose observations and kills were recorded in the Canoe Valley north of the Big Bend on the Columbia.

During the fall and winter of 1807–1808, David Thompson (1800–1812*) established Kootenay House on Lake Windermere in the Columbia Valley. At first, Thompson and his party suffered near starvation, but by late autumn natives began arriving with Elk and deer to trade. Thompson's journal entries for the winter of 1808–1809 indicated a similar pattern, but then chronicled a shortage of game. Except for this brief period, Thompson generally reported a lack of food and a near absence of game in the Columbia Valley, as well as in other areas west of the Continental Divide (White 1950; Belyea 1994).

Discussion

Judging the Validity of Early Reports

Most ecologists who have used written records to estimate the early abundance of wildlife have made little or no attempt to judge the validity of their historical source materials (e.g., Murie 1940; Byrne 1968; Nelson 1969a, 1969b, 1970; Gruell 1973; Houston 1982; Schullery and Whittlesey 1992; Morgantini 1995). But as Forman and Russell (1983: 5) asked, "If we read something written today, do we automatically believe it? If we read something written a long time ago ... do we believe it?" They noted that "Too often the answer to the last questions is 'yes', *simply because information is scarce and the statement is old* [emphasis in original]." Historians, however, have developed standard source-evaluation techniques that can be used to gauge the validity of historical statements regarding the 1792–1872 distribution and abundance of ungulates in the Canadian Rockies (Rusco 1976; Price 1980; Forman and Russell 1983; Black-Rogers 1986). These include (1) first- or second-hand observations and the credibility of the observer, (2) purpose or possible bias of the statements, (3) author's knowledge of the subject, and (4) context of the statement including negative information.

(1) First- or second-hand observations. Did the author personally make the observation reported, or was it learned second- or third-hand? Was it written

at the time of the event or was it written long after the fact based solely on memory? Was the observer credible? And do the statements appear to be within reason?

As explained earlier, we relied primarily on first-person historical accounts, and to the best of our knowledge, other first-person journals of comparable quality are not known to exist for the Canadian Rockies. There are other narrative accounts of early exploration, but these were not included in our analysis because historians have determined that narrative accounts are not as accurate as first-person journals written at the time of the event (MacLaren 1984, 1985, 1994a, 1994b, 1994c). White (1991: 618) noted that daily journals kept by early western travelers often differ from their later narrative accounts because the narratives were written to conform with accepted social myths. Unlike journals, which were usually written for personal use, narratives were written for publication and had to conform to accepted social traditions if they were to be widely read and financially successful (Cronon 1992; Pratt 1992; Demeritt 1994; Wishart 1997; Kearns 1998). During the 1800s, the myth that the West was a "Garden of Eden" teeming with wildlife but overrun with hostile "savages" colored most narratives (White 1991: 613–632).

All historical accounts reported here appear to have been written by the observer at the time of the event or shortly thereafter. Several, however, do contain some second-hand information relating to the early abundance of Elk and other ungulates. When Hector (Spry 1968) was camped near the head of the Pipestone River, for instance, he included a description of how two years earlier one of his native hunters had killed Bison in that location. This and comparable accounts are clearly second-hand information and are not as reliable as if the writers had actually seen the animals themselves.

Of the more than 20 historical accounts we summarized, all appear to have been written by credible observers, and none appear to have exaggerated what they saw or how many animals they found, except perhaps Simpson (see below). We did not encounter instances of wild exaggeration in these journals as has been reported in other studies (Kay 1990: 277–278, 1995b).

(2) Purpose or possible bias of the statement. "Did the author of the statement have a special interest or bias which may have colored the statement?" (Forman and Russell 1983: 6). Or did the author color his entire journal?

Since most of the journals we used were not written with an intent to publish, and many have not been published to this day, there appears to have been little reason for these people to have biased their chronicles as regards wildlife, though, other types of cultural biases are found in all European

accounts (Cronon 1992; Pratt 1992; Demeritt 1994; Wishart 1997; Kearns 1998). Only George Simpson (1841*; Merk 1931) may have had a reason to be overly optimistic about how much game his fur brigades could expect to find in the Canadian Rockies. He was in the business of promoting the fur trade, and local food supplies were exceedingly important for they lowered costs and increased profits. During the height of the fur trade, the Hudson's Bay Company maintained posts on the Canadian prairies whose primary purpose was to secure dried meat and pemmican to provision posts farther north and west where game was not abundant.

There is another source of bias in these journals, however, which is much more difficult to address. The procedures we used to compile our summary tables assume that animals were seen, killed, and recorded in proportion to their historical abundance. This may or may not be an appropriate assumption. Rare animals or highly prized game animals, such as Elk, may have been recorded more consistently than common species. It is well known that people have a tendency to more frequently write down events which are of importance or interest to them (Rusco 1976). Thus, we suspect that a higher proportion of Elk sightings, sign, and kills were recorded by early visitors to the Canadian Rockies than were similar data on other animals, because Elk were probably more important to them than were the smaller ungulates. There certainly is no indication that Elk would have gone under-reported or unreported if they had actually been encountered by early explorers (Keigley and Wagner 1998).

(3) Author's knowledge of the subject. Although few early explorers of the Canadian Rockies had any formal zoological training, we assumed they could tell the various ungulate species apart on sight. It would, though, be more difficult to distinguish between their sign. Could early explorers, for instance, tell deer tracks from Bighorn Sheep tracks, or Black Bear from Grizzly Bear tracks, or Wolf, Coyote, and Mountain Lion tracks apart? There simply is no way to tell. It would even be more difficult to identify animal calls, such as the howls of Wolves and Coyotes or the screams of Mountain Lions.

(4) Negative information and the context of early statements. When early explorers reported little or no game does that mean they actually saw few animals, or that they simply did not bother to write down a description of all the animals which were seen? Is negative information data? Murie (1940: 2) contended that "negative evidence must yield to positive evidence because failure to report game does not disprove its abundance," while Gruell (1973: 10) claimed that "the failure to mention sightings of Elk in early reports was not in itself positive evidence that they were not plentiful in the mountains." Morgantini (1995*: 27) also argued that "when ...

reports fail to mention the presence of Elk or when they indicate a general scarcity of game animals, no clear conclusion can be made." Although positive statements are preferable to silence, we submit that negative information can be just as important. We also maintain that what people do not say is, at times, even more important than what they record. For instance, negative information avoids the problems of exaggerations and misleading statements discussed above (Price 1980).

There are two ways to check the validity of the negative information contained in the historical source materials for the Canadian Rockies. First, if people recorded wildlife sightings or kills before entering the mountains, but not while they were in the Rockies, that strongly suggests they were careful observers whose lack of record really means they saw little game (Kay 1990, 1995b). This certainly is true of the journals used in this study. While David Thompson, for instance, recorded relatively little game in the Rockies, his journals contain numerous accounts regarding the abundance of game on the Canadian prairies (Tyrrell 1916; Coues 1965). The same is true of other explorers. Accounts of seeing and killing game on the prairies were common but those entries declined precipitously when parties entered the mountains or passed into the Columbia Valley (Thompson 1800-1812*).

Second, the majority of early journals exhibit the same general pattern. That their writers were removed in time and space, yet reported similar ungulate sighting and kill rates, would imply that those were valid patterns, not aberrant occurrences (Kay 1990, 1995b; Keigley and Wagner 1998). For instance, Canada's early explorers generally reported more Bison, Elk, and deer in the Foothills than in the Rockies, and without exception, all parties who visited Kootenay Plains reported more game there than at any other place in the mountains.

Why Did Early Explorers See So Little Game?

At least six reasons, other than an out-right scarcity of animals, have been advanced to explain why early explorers saw relatively little game and so few Elk in the Canadian Rockies. These include: (1) Large, noisy parties chased all the game out of the country or drove the animals into hiding, in advance of their passing; (2) Game in summer was primarily at higher elevations away from the most frequently traveled routes. That is to say, people traveling through winter ranges in summer would not be expected to see game; (3) Hunting drove game away from established trails and posts such as Jasper House; (4) It was more difficult to see and kill game in the heavily wooded mountains than on the plains where reports of game were common; (5) Fur brigades traveled fast and light and did not have time to hunt; and (6) Fire and disease decimated game populations ca. 1850.

(1) Some early visitors to the Canadian Rockies suggested that their large, noisy parties scared off game before it could be seen. While this no doubt was true to some degree, we do not believe that it can be cited as a major reason so little game was seen or killed in the mountains. First, if anything, parties on the plains were larger than those in the Rockies, and as noted, parties on the prairie had little trouble procuring game (Thompson 1800–1812*). Second, many parties split into smaller groups to explore the mountains and several sent out hunters ahead of their line of march. Most of those smaller groups were no more successful at seeing or killing game than were the larger parties (Thompson 1800–1812*). Many hunters searched diligently for days yet saw and killed very little. Finally, although Elk are very sensitive to hunting disturbance associated with motor vehicles and modern high-powered rifles (Lyon 1979a, 1979b, 1983; Edge et al. 1985a, 1985b), there is little evidence that Elk simply hid from early explorers, or that if they had, they would have been successful. Besides, of the ungulate species found in the Canadian Rockies ca. 1800–1870, Elk were one of the easiest to hunt (Frison 1991). That is to say, if Elk were as common in the past as they are today, there is no logical reason why early explorers would not have seen and killed a great many Elk (Keigley and Wagner 1998).

(2) The argument that early explorers saw little game in the Canadian Rockies because all the animals summered at higher elevations away from traveled routes is based on the assumption that even in the absence of human disturbance, Elk would summer there to secure better forage or to avoid insects. This assumption, though, appears to be without merit. When Wyoming's Grand Teton National Park was expanded to its present size during the 1950s, no Elk summered on the valley floor. Since then, a summering herd of 3000 to 4000 Elk has built up in that area (Boyce 1989). A summer Elk herd has also become established on the National Elk Refuge at even lower elevation in Wyoming's Jackson Hole (Boyce 1989). That herd would have continued to grow except Wyoming Game and Fish set special hunting seasons to eliminate those animals because they did not want Elk summering on the winter range (Boyce 1989).

Summering Elk herds have also become established on Yellowstone National Park's northern winter range. Several hundred Elk now summer on Mt. Everts, Brunsen Peak, and around Mammoth (Kay 1990). In Montana, summering Elk herds have become established on several winter ranges owned by the Montana Department of Fish, Wildlife and Parks. Those herds would also have expanded beyond their present numbers, except that Montana set special hunting seasons to eliminate them because the state does not want Elk summering on

its winter ranges (Kay 1990). The same is true in the Canadian Rockies. Today, several hundred Elk summer in Banff's Bow Valley (Woods 1991; White et al. 1998), on the Ya Ha Tinda (Morgantini 1995*), and in Jasper's Athabasca Valley (Dekker 1985).

In addition, Elk do not need to forage at higher elevations to meet their nutritional requirements. Lewis and Clark (1893), Maximilian (1966), and other early explorers repeatedly saw and killed large numbers of Elk on the Great Plains, as did Palliser (1969), David Thompson (Tyrrell 1916), and others on the Canadian prairies. In the hottest, driest part of Washington State's Columbia Basin, a resident Elk herd not only increased at near the theoretical maximum rate for that species, but bulls grew large antlers indicative of excellent nutritional conditions (McCorquodale et al. 1988, 1989; McCorquodale 1993). This herd occupies a grass-sagebrush (*Artemisia* spp.) range with no tree cover except for a few small riparian areas. If Elk can summer there, they surely could summer on any winter range in the Canadian Rockies.

Furthermore, several parties traveled through the Athabasca Valley in late fall or early winter when snow and cold temperatures would have forced ungulates onto low-elevation ranges, yet they still failed to observe any Elk. So even when early explorers traversed what are now major Elk wintering areas during winter, they did not report seeing the concentrations of animals that are common today. On many of these winter crossings, the explorers also complained of a lack of food, making it doubtful that they would have failed to report or somehow have overlooked Elk if the latter had been present in any numbers. Moreover as noted above, people who wintered at Jasper House killed few Elk or other animals and, in general, were short of food.

(3) Some have suggested that early visitors to the Canadian Rockies saw relatively little game because fur-trade associated hunting had killed off all the animals or at least had driven them away from the most traveled routes. First, since explorers killed relatively few ungulates, other than Bighorn Sheep, it appears doubtful that this could have had a major influence on ungulate distribution or abundance. It is clear, however, that David Thompson, the first European known to have traversed the North Saskatchewan, Athabasca, and the Columbia Valleys, reported seeing and killing more ungulates, and especially Bison, than later parties. Similarly, it is apparent that the establishment of posts, such as Jasper and Kootenay House, placed additional pressure on game resources. Nevertheless, we do not believe there was enough fur-trade hunting pressure, in and of itself, to have killed out Elk and other ungulates.

Moreover, there was more ungulate winter range in the Canadian Rockies ca. 1800 than there is today due to a high frequency of low-intensity fires that

maintained open grassland communities at the expense of forests (Van Egmond 1990; Kay et al. 1994*; Kay and White 1995; White et al. 1998). The frequent burning also enhanced forage production and quality (Bailey 1986). Therefore, if food was the only thing that limited herbivore numbers, ungulate populations ca. 1800 should have been 2–3 times higher than what they were in the 1950s–1960s when Wolves were absent (Peck 1980, 1988; Van Egmond 1990; Peck and Peek 1991). That is to say, in our estimation the major winter ranges in the Bow, Athabasca, and North Saskatchewan valleys could each have supported around 10 000 ungulates and that on the Columbia perhaps another 100 000. Since even the earliest explorers did not report anywhere near these numbers of animals, some factor other than food must have limited those populations (White et al. 1998). Thus, while fur-trade-induced hunting may have contributed to declining ungulate populations, there is no evidence that it alone killed off all the game and especially not Elk. Besides, there is no evidence that the fur trade had any significant impact on Banff's Bow Valley, and game populations and Elk numbers were just as low there ca. 1840 as they were in other, more traveled, areas of the main Canadian Rockies. Moreover, despite repeated hunting and kills on Kootenay Plains, that is the one area in the mountains where all parties continued to report game throughout the 1800s.

(4) It has also been postulated that early explorers reported more game on the plains than in the Canadian Rockies because game was easier to see and kill where there was no forest cover. While ungulates certainly are more visible in the open than in the timber, two lines of evidence suggest that this was probably not an overriding consideration. First, even in the mountains most ungulates feed in openings where they can be easily seen from opposing hillsides or mountain tops, especially using binoculars or telescopes that were often carried by early explorers. Second, repeat photographs show that forests in the Canadian Rockies have both grown up and thickened up since the late 1800s due to modern fire suppression and the elimination of aboriginal burning (Kay 1995a; White et al. 1998). In reviewing early photographs (Kay et al. 1994*; Kay and White 1995), one is struck by how open much of the country was when the Canadian Rockies were first explored, especially lower montane valleys where most parties traveled. Thus, animals hidden from view by dense forests would be a greater concern today than in the past (Anderson 1998). It must also be remembered that early explorers traveled by foot or on horseback which allowed them ample opportunities to look for game. They did not speed by at 100 km per hour as most people do today. Since early explorers were living off the land, or at least tried to, they also had more incentive to locate game.

(5) Many explorers traveled relatively quickly (for that day and age, but not by modern standards) which could possibly explain why they saw few Elk or other ungulates. We believe, however, that rapid travel itineraries were often mandated by a lack of game, not the cause of reduced wildlife sightings. It is clear from journal entries that many parties would have stopped to rest except that a lack of food forced them to continue (Thompson 1800–1812*). After a section of country was known to hold little game, and therefore offered little chance of subsistence, then it was logical for fur brigades to push on as rapidly as possible to reach the next supply point, such as Kootenay Plains or Jasper House or even Fort Edmonton. Moreover, exploring parties did not report more game than faster traveling fur brigades. Both Hector and Southesk, for instance, clambered up and down mountain peaks and travelled at a leisurely pace accompanied by experienced native and Metis hunters, yet neither party saw an Elk east of the continental divide.

(6) Hector (Spry 1968: 326) suggested that a combination of large forest fires and disease decimated game herds in the Rocky Mountains ca. 1850. While this is an interesting explanation for a supposed decline in ungulates (Morgantini 1995*: 25), there is no indication from Hector's account that, with the exception of Bison, numbers of animals were any lower than what travelers had found in the early part of the century. For instance, on 15 September 1858 Hector descended the North Saskatchewan to Kootenay Plains where large numbers of Bighorn Sheep were seen, including "a flock of at least a hundred rams [which] rushed close past me, so close, indeed, that I hit them with stones" (Spry 1968: 328). During the fall of 1859, Hector again reported "several hundred" Bighorn Sheep near Kootenay Plains (Spry 1968: 443). Thus in 1858–1859, Bighorn Sheep appeared to have been every bit as numerous on Kootenay Plains as they were earlier in the 1800s, which does not support the hypothesis that some unknown disease ravaged game animals ca. 1850. Moreover, there is no evidence that diseases decimated ungulate populations anywhere in western North America ca. 1800–1870 (Kistner 1982). Even if European-introduced livestock diseases, such as anthrax or hoof-and-mouth, were somehow transmitted to wildlife, it is doubtful that they would have completely decimated game populations (Carbyn et al. 1993). Finally, burning of the forest would have created feeding areas and favored game populations, not contributed to their decline (Van Egmond 1990).

Summary and Conclusions

Despite the difficulties of dealing objectively with written historical materials, we believe that continuous-time analyses of early first-person journals

support the following general conclusions relating to the ca. 1800-1870 distribution and abundance of ungulates in the Canadian Rockies.

(1) Bighorn Sheep were the most frequently seen and killed ungulate in the main Canadian Rockies. Bison were next, followed by Moose, Mountain Goats, Elk, and deer. Elk did not dominate the ungulate community in the past as they do today.

(2) The earliest explorers who visited the Athabasca and North Saskatchewan Valleys generally saw and killed Bison, or at least observed recent sign. Later parties reported old buffalo skulls, but few actually saw Bison or fresh sign. Today, free-ranging Bison have been absent for over 100 years (Kopjar 1987*).

(3) Bison, Elk, and deer were more frequently observed in the Foothills than in the main Rockies. There is evidence that Bison moved from the Canadian prairies to the Foothills and probably into the mountains, as well (Moodie and Ray 1976; Morgan 1980; Langemann 2000).

(4) Within the mountains, game was more frequently seen and killed on Kootenay Plains than in any other area. The reason for this is unclear, but the area may have been a tribal territory boundary or buffer zone (Millar 1915: 35) where native hunting was limited which, in turn, permitted higher ungulate densities (Hickerson 1965; Steffian 1991; Kay 1994, 1997a, 1998; Martin and Szuter 1999). Historical accounts indicate that no native group occupied Kootenay Plains ca. 1800-1840. After ca. 1850, the Stoney began visiting Kootenay Plains and they may have been responsible for killing-off the last of the Bison by ca. 1860.

(5) The first explorers who visited an area in the mountains usually reported more animals, and especially Bison, than parties that followed.

(6) Even the earliest game populations, however, were not what would have been expected if food had been the major factor limiting ungulate numbers. Except for a few flocks of more than 100 Bighorn Sheep, no one encountered large herds of game. The other possible limiting factors, carnivore predation and aboriginal hunting, are discussed elsewhere (Kay 1994, 1995a, 1997a, 1997b, 1997c, 1998; Kay and White 1995; White et al. 1998).

(7) The earliest explorers encountered few Native Americans or signs of native people. Despite a presence in the Canadian Rockies dating back over 10 000 years (Fedje et al. 1995), apparently there was little year-round or seasonal use of the mountains by aboriginal groups ca. 1800. This may have been the result of European disease epidemics that reduced native populations or it could have been caused by intertribal warfare (Dobyns 1983; Smith 1984; Kidd 1986; Ramenofsky 1986; Campbell 1990). While Peter Fidler noted that Peigan and Kootenay traded horses on the Oldman River during

the winter of 1792-1793, David Thompson's journals make it clear that during the early 1800s, the Peigan were keeping the Kootenay west of the Rockies by force of arms (Dempsey 1965; Belyea 1994). Prior to expansion of Peigan influence during the 1700s, the Kootenay may have permanently occupied the main Canadian Rockies and even the Alberta Foothills (Smith 1984).

(8) Later parties, however, generally observed more native peoples though encounter rates were still low. Apparently, various native groups moved into the Athabasca Valley to service the fur trade or to be near trading posts, such as Jasper House and La Rocque's Mountain House. Moreover, the Stoney moved into the Rockies from the north after the 1837-1838 smallpox epidemic decimated the Peigan and other members of the Blackfoot confederation.

(9) Hunting to supply fur-trade posts may have contributed to the decline and suppression of ungulate populations in the Athabasca Valley. This could not have been an important factor in the Bow Valley, however, because Europeans first entered that area in 1841, and because fur posts were never established in what is now Banff National Park, nor in Kootenay or Yoho.

(10) Wolves and other predators were encountered in the Canadian Rockies, and they too preyed on ungulates. There are several accounts of Wolves attacking domestic horses during winter in the Athabasca Valley.

(11) There is no evidence that Elk were common anywhere in the main Canadian Rockies or the Columbia Valley ca. 1800-1870. Even the earliest explorers, such as David Thompson, did not encounter large herds of Elk. Between 1792 and 1872, 26 expeditions spent 369 party-days in the mountains, yet they only saw Elk 12 times and only 8 animals were killed. There can be little doubt that Elk numbers during the 1800s were much lower than they are today. There is no historical evidence that large herds of Elk occupied the Bow and Athabasca Valleys until the mid-1900s. The idea that the Canadian Rockies originally teemed with ungulates or that those populations were resource limited (Woods 1991) is not supported by historical data.

Management Implications

The unbrowsed condition of vegetation in the earliest historical photographs and aspen ecology data also suggest that Elk populations were low ca. 1800-1870, while archaeological evidence suggests that ungulates were also rare in pre-Columbian times (Kay 1990, 1997b, 1997c; Kay and Wagner 1994; Kay et al. 1994*; Kay and White 1995). This raises the question of what limited ungulate communities in the past. As discussed elsewhere, we believe that a combination of carnivore predation and native hunting once kept ungulate numbers low except where

prey had refugia, such as on the prairies (Kay 1994, 1995a, 1995b, 1996, 1997a, 1998; White et al. 1998). Thus, the dramatic impact Elk are having on plant and animal communities in Banff, Yoho, Kootenay, and Jasper National Parks is not within the range of historical variability (Kay 1997c). If we measure present ecological integrity by the state and processes of the ecosystem that existed before European arrival, as others have proposed (Kay 1991a, 1991b; Woodley and Theberge 1992; Woodley 1993; Woodley et al. 1993; Wagner et al. 1995), then Banff's Bow Valley and much of the Canadian Rockies today lack ecological integrity (White et al. 1998).

Throughout North America, most national parks, wilderness areas, and nature reserves are managed to represent the conditions that existed in pre-Columbian times; i.e., so-called natural or pristine conditions. But what is natural? If Native Americans repeatedly fired the vegetation and in combination with other predators limited ungulate numbers, which, in turn, determined the structure of entire plant and animal communities, that is a completely different situation than letting nature take its course today (Wagner and Kay 1993; Kay 1995a; Wagner et al. 1995). Moreover, Canada, like many countries, has chosen to use her national parks as baseline reference areas from which to judge the health of other, more exploited ecosystems (Henry et al. 1995). But again, what is natural? If ecological conditions in Canada's national parks are changing due to reduced predation on ungulates and lack of aboriginal burning, as we have argued (Kay and White 1995; White et al. 1998), then are those parks the proper standard with which to measure ecosystem health and ecological integrity in the other areas?

Clearly, the only hope in answering these and similar questions rests with studies that focus on historical ecology and how ecosystem states and processes have changed over time (Wagner et al. 1995; White et al. 1998). Two things, though, are clear. Second-hand or narrative accounts should not be used to infer past wildlife populations nor should only selected quotes be used from first-person materials (Keigley and Wagner 1998).

Finally, if smallpox or other European diseases decimated native populations ca. 1600 A.D. as postulated by Dobyns (1983), Ramenofsky (1987), and Campbell (1990), then even the first European descriptions of the Canadian Rockies do not adequately convey the effect that much larger pre-Columbian aboriginal populations had on their environment (Geist 1996). That is to say, if Native Americans limited ungulate populations as has been proposed (Kay 1994, 1995a, 1997a, 1998), and if smallpox decimated aboriginal populations 500 years ago, then wildlife numbers would have increased before the first European explorers arrived

(Preston 1997). Thus, journal accounts may suggest higher ungulate populations than what existed in pre-Columbian times. This pattern, in fact, is reflected in the archaeological record. Easily overexploited ungulates such as Elk and Moose first appear in archaeological sites in any numbers only 500 years ago (Yesner 1989; Frison 1991; Kay 1994, 1997a). Before then, native hunting was so intense and ungulate populations so low, that few animals were actually killed. Of over 60 000 ungulate faunal remains unearthed at more than 300 archaeological sites in the U.S. and Canadian Rockies, only 3% were Elk and less than 1% were Moose (Kay 1994, 1997c, 1998; Kay et al. 1994*).

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Staging Little Gulls, *Larus minutus*, on the Niagara River, Ontario: 1987–1996

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Since its first definite sighting in Ontario in 1930, the Little Gull (*Larus minutus*) has become an uncommon, but increasingly regular, migrant in the Great Lakes region on its way to and from the wintering areas on the Atlantic seaboard and Mississippi River. Over a period of 10 years (1987–1996), Little Gulls and Bonaparte's Gulls (*Larus philadelphia*) were counted as they flew over the Niagara River, Niagara-on-the-Lake, to their nocturnal roost in Lake Ontario to document the timing of migration and to monitor gull numbers. Counts generally began in October or November (range 3 October – 21 November) and continued until the fly-past ceased for winter; counting was resumed in early spring to document spring migration return dates. Altogether, 768 Little Gulls were counted and the vast majority (64.9%) of these were in the 1994/1995 (214) and 1995/1996 (285) seasons. This was not due to variation in coverage; in 1994/1995 no counts were made in the autumn season and were made only from 13 January to 1 May ($n = 11$). In the seasons for which coverage was similar there was a marginally significant increase in numbers of Little Gulls counted during the spring season, whereas there was a decrease in autumn counts. A comparison of Little Gull counts made at the Niagara River with those made at other staging areas in Ontario indicated that the Niagara River and Long Point may be the most important staging areas on the continent. Recent declines at Long Point coincide with an increase on the Niagara River, suggesting that preferred feeding areas have changed.

Key Words: Little Gull, *Larus minutus*, Niagara River, staging, roost counts, Ontario.

Since the discovery of the first Little Gull (*Larus minutus*) nest in the New World, at Oshawa in Ontario in 1962 (Scott 1963), the numbers of breeding records and sightings of this species have increased markedly in both Canada and the United States (see Weseloh 1994 for a review; Ewins and Weseloh 1999). Whether this increase can be attributed to its recent colonization of the New World as proposed by most authors (e.g., Baillie 1963; Hutchinson and Neath 1978; Cramp and Simmons 1983; Godfrey 1986; Austen et al. 1994) or whether the Little Gull has been overlooked for decades, remains somewhat of an enigma (McRae 1989). In view of the discovery of nests in the Hudson Bay Lowlands during the Ontario Breeding Bird Atlas (Weseloh 1987), during waterfowl surveys in northern Ontario (Carpentier 1986), and studies of gull species in northern Manitoba (McRae 1984), the latter seems more likely. However, in contrast to its breeding status, the Little Gull has been known since 1930 as a "rare but regular" associate of the huge numbers of Bonaparte's Gulls (*Larus philadelphia*) that stage in the Great Lakes and eastern North America on their way to the Atlantic seaboard or Mississippi wintering areas (Baillie 1963; Beardslee and Mitchell 1965; Goodwin 1995). There are also increasing records of Little Gulls from the Prairie Provinces (e.g., Taylor 1991).

Little Gulls sometimes occur in fair numbers on autumn and spring migration in the Long Point region; McRae (1989) suggested that this was the most important staging area in North America. Another area where Little Gulls stage, in this instance in association with Bonaparte's Gulls, is on the lower Niagara River and adjacent Lake Ontario in southeastern Ontario. Prior to 1938, the Little Gull was unknown in this region (Beardslee and Mitchell 1965), perhaps because it was overlooked amongst the huge flocks of Bonaparte's Gulls. Not only were birders of that period unfamiliar with the species, but they also lacked the sophisticated optical equipment and field guides necessary for accurate gull identification (Weseloh 1994), at least until the 1960s. Perhaps more critically there are probably now at least 100 times more observers than there were historically and bird-watchers today spend much more time birding than previously.

Since that time there has been a gradual increase in the number of sightings of Little Gulls on spring and fall/early winter migration (Andrle 1977), although reports of sightings were greatly under-represented in the regional summaries for American Birds from 1948–1956 (Weseloh 1994). Weseloh (1994) suggested that increases in Little Gulls took place over three distinct time periods. (1) Between 1955–1970 Little Gull sightings were reported annually,

with a maximum count of 21 individuals; (2) There was a six-fold increase in the number of reported sightings between the beginning and end of the second period (1971–1984) with a maximum count of 121 birds and a four-fold increase in numbers of Little Gulls reported on Christmas Bird Counts (CBCs) between 1971 and 1984; (3) Since 1985 the rate of Little Gull sightings overall has increased three fold, and the number of sightings on CBCs has increased five fold compared to the period 1971–1984.

In 1986, GB began making autumn and spring counts of gulls (particularly Bonaparte's Gulls) flying along the Niagara River to roost on Lake Ontario, in order to document the importance of this region for staging gulls, and to determine temporal and seasonal variation in numbers (Kirk and co-workers, unpublished manuscript). This provided a unique opportunity also to document the numbers of Little Gulls staging in the area. Interestingly, the period during which GB counted Little Gulls coincides closely with the third period of increase reported by Weseloh (1994). In this paper, we use counts of Little Gulls made on the Niagara River between 1986 and 1996 to test two hypotheses. First, we compare autumn and spring counts in count seasons with similar coverage to see if a prediction that significantly more gulls were counted in the spring is valid. Second, we examine whether Little Gull numbers have increased in the Niagara River over the 10-year count period and whether there were any changes in the temporal pattern of occurrence of the species in this region. We also compare the season totals with counts made at Long Point, which is believed to have the highest concentration of Little Gulls on migration in Ontario (McRae 1989).

Methods

During the autumn (October–January) and spring (March–May) staging periods many small gulls (almost entirely Bonaparte's Gulls) fly north over the lower Niagara River each late afternoon/evening to roost on Lake Ontario (0.75 to 1 km north of Fort Niagara). On the following morning, many Bonaparte's Gulls fly up river to feed, as demonstrated by a dawn count conducted by P. J. Ewins and DVW in December 1994.

The observations on which this paper is based were made (almost entirely by GB) from a stationary car parked at the edge of the Niagara River (Yacht Club). Although GB generally began counting before the first gulls flew down the river, on some occasions gulls had already started flying to the roost when he arrived. If large numbers of gulls were thought to have been missed in this way then no count was made. Although GB attempted to standardise timing of counts, the exact time periods depended on time of year and the weather condi-

tions. For the autumn count period the timing of counts was 15:30–17:55 (median 16:15), whereas in the spring it was from 17:00–19:50 (median 18:00). Counts were ended when no gulls flew by for a 10–15 minute period or when it became too dark to identify gulls accurately (Kirk and co-workers, unpublished manuscript).

Weather conditions had two important effects. First, they determined whether gulls could be identified accurately. During southerly winds, gulls flew in loose flocks over the river and above the tree line on the United States side of the river, making it difficult or impossible to separate Bonaparte's and Little Gulls, particularly in poor light conditions (Bellerby 1994; see Grant 1982 for identification of these two species). By contrast, when winds were northerly, gulls flew in more compact flocks at lower altitude (Bellerby 1994). Weather also determined the time at which gulls came to roost; gulls went to roost later during bright sunny conditions than in dull cloudy weather.

For the eight seasons with most complete coverage, the numbers of visits when gulls were counted varied from 12 to 43 (median = 20). Coverage was designed to coincide with the staging period for Bonaparte's Gull; hence when the fly-past of Bonaparte's Gulls ended, GB stopped counting. Thus, in the early years of study (1987, 1987/1988) the spring return was not documented at all as no counts were made after February. In the 1986/1987 and 1994/1995 seasons, no counts were made in the autumn (1986 and 1994) and counts only began in January (1987 and 1995). Also GB did not begin counts until October, although Bonaparte's and Little Gull movements began as early as late July or early August (Beardslee and Mitchell 1965). We defined the autumn and early winter staging period (the fly-past — Bellerby 1994) as 3 October to 18 February based on inspection of counts of Bonaparte's Gulls (Kirk and co-workers, unpublished manuscript). It was not possible to do this simply by inspection of Little Gull counts because of the very low numbers involved.

Because counts were low and Little Gulls were seen infrequently in most years, there were insufficient data to model statistically the effects of season, time of year, weather conditions and count duration as we did for Bonaparte's Gull (Kirk and co-workers, unpublished).

Because the number of visits varied between periods we used a randomization test written in FORTRAN (B. T. Collins, personal communication) to test whether counts differed significantly between the spring and autumn periods after correcting for the number of counts. We examined trends in numbers of Little Gulls in the autumn and spring periods separately, and for all data combined to see if there were statistically significant increases or decreases in the numbers of birds. For these analyses we

TABLE 1. Autumn/early winter counts of Little Gulls on the Niagara River between 1987–1996.

Year	Autumn/early winter count duration	Maximum count	Date of maximum count	Autumn/early winter total	N ¹ (% of counts)
1987	8 January–13 February ¹	22	31 January	74 ^a	13 (61.5)
1987/1988	10 October–18 February	7	4 February	34	43 (20.9)
1988/1989	7 October–3 February	7	2 November	44	25 (52.0)
1989/1990	3 October–9 February	5	9 February	18	24 (33.3)
1990/1991	30 October–5 February	3	1 November	10	23 (34.8)
1991/1992	4 November–13 February	2	31 January/3 February	9	26 (26.9)
1992/1993	22 October–2 February	1	17 January	1	14 (7.1)
1993/1994	11 October–17 January	3	23 December	6	15 (20.0)
1994/1995	13 January–6 February	11	29 January	18 ^a	6 (50.0)
1995/1996	21 November–19 January	3	19 January	5	11 (27.3)
Overall ²	3 October–18 February	22	31 January		

^aNote there were no autumn counts (October to December in these years)

¹N = number of counts per season

²Overall row shows range or median date/count

combined data from different counts; strictly speaking this may not be valid statistically because many of the same individuals staged on the Niagara River for an unknown period, and GB therefore may have counted the same individuals two or more times.

Some researchers have suggested that the number of Little Gulls counted is positively correlated with counts of Bonaparte's Gulls (Burger and Brownstein 1968); we use Spearman rank correlation coefficients to test whether there was any significant association between the two species. Finally, we attempted to compare counts made on the Niagara River with those made at Long Point on the north shore of Lake Erie to assess the relative importance of these two regions for staging Little Gulls. For data handling and analyses we used SAS PC software (SAS Institute 1989).

Results

Altogether, a cumulative total of 768 Little Gulls was counted during the autumn/early winter staging

period (3 October to 18 February) and the spring return over the 10-year study period. By far the majority of gulls (64.6%) was counted in the 1994/1995 and 1995/1996 seasons (see Figure 1). This was not just due to differences in coverage (Table 1); for example counts in the 1994/1995 season were made only from 13 January to 5 May, yet that season had the second highest count total.

The date of the maximum count varied from 2 November to 20 April; discounting the first two study seasons when no spring counts were made (1987 and 1987/1988), in two other of the early study years the date of maximum count was in the fall/early winter, whereas in later years the maximum count was always made in March or April. Spring return dates ranged from 24 February (which probably involved overwintering birds) to 13 April (the median spring return date was midway between 28 March and 3 April; Table 2).

Considering seasons with similar coverage only, 127 Little Gulls were counted in the autumn/early

TABLE 2. Spring counts of Little Gulls on the Niagara River between 1987–1996.

Year	Spring return ¹	Date of maximum count	Maximum count	Cumulative total	N ² (% of counts)
1987	^a
1987/1988	^a
1988/1989	3 April–13 April	3 April	3	3	2 (50.0)
1989/1990	8 Mar.–13 April	8/12 March	1	2	5 (40.0)
1990/1991	28 March–11 April	28 March	13	18	4 (75.0)
1991/1992	13 April	13 April	26	26	1 (100.0)
1992/1993	12 April–24 April	12 April	20	26	3 (100.0)
1993/1994	12 April–20 April	20 April	5	8	2 (66.7)
1994/1995	22 March–1 May	7 April	37	162	13 (92.3)
1995/1996	24 February–17 April	5 April	78	280	16 (81.3)

^aThere were no spring return dates documented in these seasons

¹Spring return indicates arrival of first Little Gull, last date is end of spring count

²N = number of counts per season



FIGURE 1. The number of Little Gulls observed per week at the evening fly-past at Niagara-on-the-Lake, autumn-winter-spring 1986–1996. Weekly totals commence with 3–10 October and continue through 1–7 May. The total number of surveys conducted during each season (N) and the mean number of surveys per week, when at least one survey was conducted, are given following the “month” caption below the x-axis. Data are plotted for all weeks in which at least one survey was conducted, including weeks during which no Little Gulls were observed; e.g., during the first week of November 1987/88 no surveys were conducted and no data are plotted, during the second week at least one survey was conducted and one Little Gull was observed, during the third week at least one survey was conducted and zero Little Gulls were observed.

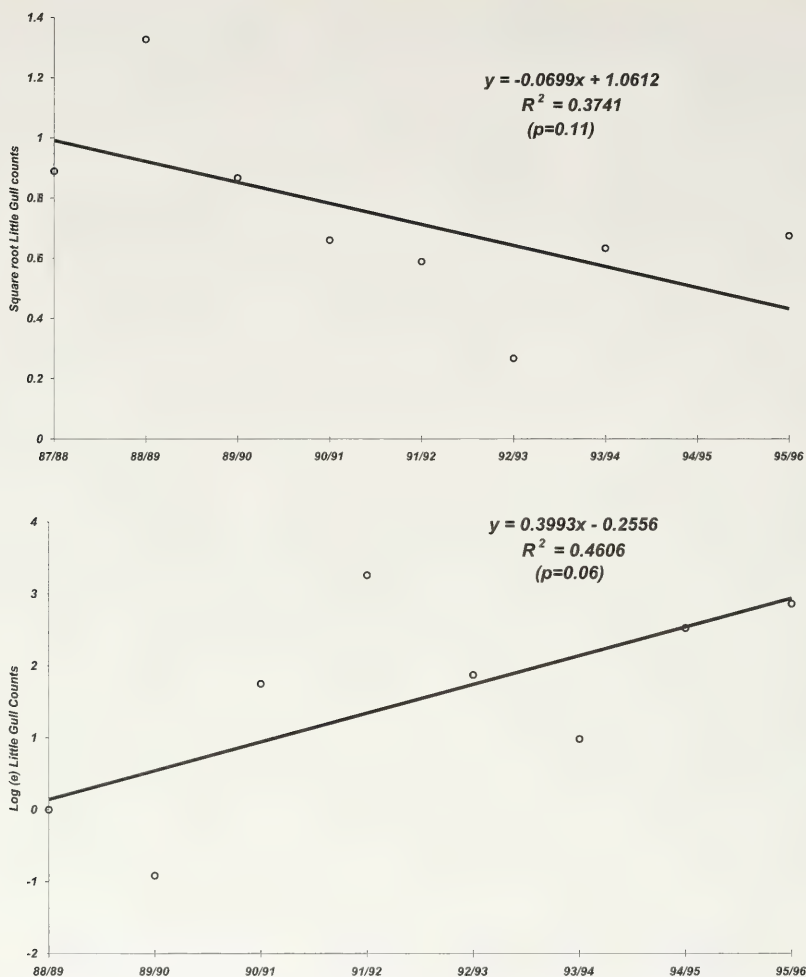


FIGURE 2. Linear regression of Little Gull counts (corrected for number of visits) in relation to year of count: (above) Autumn; (below) Spring.

winter period and 529 during the first part of the spring return. Maximum counts ranged from 1–22 in the autumn/early winter period and 1–78 in the spring return period (Tables 1–2). Thus combined totals were lower in the autumn/early winter than in the spring (Figure 1).

There was a tendency for more Little Gulls to be counted during the autumn/early winter in the first few years of study (i.e. 1988/1989 and 1989/1990) than later, when more Little Gulls were counted in the spring. That was partly because more spring counts were made in recent years (e.g., two counts in spring 1988/1989 compared to 16 counts in 1995/1996; Table 1). However, when we adjusted counts for the number of visits (log-transformed data) the linear regression of spring counts on year demonstrated a marginally significant increase in gull numbers (SLR; $F_{1,6} = 5.27$, $r^2 = 0.468$, $P =$

0.0614; Figure 2a). Conversely, there was a non-significant decline in counts of Little Gulls made during the autumn period ($F_{1,6} = 3.61$, $r^2 = 0.376$, $P = 0.1066$; Figure 2b). Although most correlations between autumn/early winter counts of Bonaparte's Gulls and Little Gulls were negative, in only two seasons did they approach statistical significance (1990/1991 $r_s = -0.396$, $n=23$, $P = 0.0616$ and 1991/1992, $r_s = -0.396$, $n=26$, $P = 0.0616$). For the combined spring and fall counts only one of 10 tests was significant ($r_s = 0.566$, $n=18$, $P = 0.0143$).

Discussion

Relative importance of the Niagara River

Our results suggest that the Niagara River is a very important staging area for Little Gulls, as it is for Bonaparte's Gulls (Kirk and co-workers, unpublished manuscript), particularly during the spring.

The recent increase in spring counts of Little Gulls at the Niagara River is supported by a comparison with Ontario seasonal summaries for spring (1 March to 31 May) and autumn (1 August to 30 November) reported in National Audubon Society Field Notes (ASFN; Ridout 1994, 1995a,b, 1996a,b). A maximum of only five Little Gulls was counted at the Niagara River in 1994, or less than 10% of the provincial total of 52 Little Gulls; the maximum count (16 birds) was at Whitby (east of Toronto) on 29 April (Ridout 1994). By contrast, out of a total of 121 Little Gulls counted throughout the entire province during the spring season of 1995, 54 (44.6%) were from the Niagara River alone (Ridout 1995b). Although Ridout (1996b) did not give provincial totals for the spring of 1996, a maximum of 78 Little Gulls was counted on the Niagara River (5 April), and 60 at Oshawa Marsh (29 April). We could not compare autumn totals province-wide with those made at the Niagara River because of lack of coverage for the months prior to October.

Trends in Little Gull numbers

Our results suggest that the number of Little Gulls staging on the Niagara River has increased in recent years, and dramatically so in the last two years of study. However, there was a suggestion that numbers had decreased in the autumn/early winter period and increased in the spring. We do not believe our data are sufficiently robust in themselves to support such a conclusion, but the decrease in fall numbers is supported by an analysis of Christmas Bird Counts (CBC) in 1920–1989 (Weseloh 1994). Albeit from a short time span (December–January), that analysis indicated that the autumn/early winter distribution of Little Gulls was previously centred on the Niagara River [e.g., Speirs (1985) cited a report of 29 Little Gulls on 4 November 1973], but has shifted to Long Point. For example, there were eight and 21 Little Gull on 4 November 1973) but has shifted to Long Point. For example, there were eight and 21 Little Gulls counted at Long Point for the CBC in 1993–1994 and 1994–1995, respectively at Long Point, whereas for the Niagara River the counts were only two and one birds (LeBaron 1994, 1995). However, there were no Little Gulls on the 1995–1996 Little Gull CBC at Long Point (LeBaron 1996). We caution that CBC data may be misleading for monitoring trends in Little Gull numbers because whether or not gulls are counted depends on whether water bodies are frozen.

Conversely, the more recent increases in spring counts on the Niagara River coincide with a decrease in Little Gulls at Long Point (J. D. McCracken, personal communication). For example, in 1996 the spring season count of Little Gulls was 78 on the Niagara River, but none were reported for Long Point (Ridout 1996b). This suggests that Little Gulls may have different spring and autumn migration

routes; interestingly, in the Camargue (southern France), the overland route is used more in the spring, particularly by adults, than in the autumn (see Cramp and Simmons 1983 for references).

Timing of staging

Because GB did not begin counting until October, he probably missed large numbers of Little Gulls that arrive with Bonaparte's Gulls in late summer and early autumn (July–September). Although the earliest autumn record for the Niagara Region in the period 1938–1960 was 23 August (1953), the normal staging period was considered by Beardslee and Mitchell (1965) to be 1 September to 11 January. During the 1960s, in the western New York region, the Little Gull occurred from 8 August to 21 January (Burger and Brownstein 1968). Weir (1989) recorded the average autumn arrival date in the Kingston area as 29 September (earliest was 8 August 1960) but this is not representative of southern Ontario in general. In southern Ontario the first autumn migrant Little Gulls arrive with the first waves of Bonaparte's Gulls, typically on 26 July at Point Pelee (A. Wormington, personal communication); the four earliest dates for Point Pelee for Little Gulls are 14 July 1983; 16 July 1978, 18–20 July 1995, and 22–23 July 1994.

Furthermore, Burger and Brownstein (1968) suggested that there were two peaks in numbers of Little Gulls on their autumn/early winter migration. While that may be true, judging by the low numbers counted it seems difficult to ascertain and the authors may have been referring to the well-known bimodal migration pattern of Bonaparte's Gulls during autumn/early winter staging (Beardslee 1944). In the spring, the earliest recorded in the Niagara Frontier Region was 7 April (1946), followed by a bird at Dunkirk Harbour on the 10 April (Beardslee and Mitchell 1965). A review of seasonal dates is presented by Speirs (1985) for other sites in the province, as well as the Niagara River.

Our results suggest that either Little Gull populations increased in recent years and/or there has been a shift in staging areas (from Long Point to the Niagara River area, at least in spring). If continued, standardized counts may be useful for examining population trends or shifts in movements/feeding patterns or wintering areas in Little Gulls, as recommended for Bonaparte's Gull (Kirk and co-workers unpublished manuscript). The Niagara River provides a unique opportunity to count gulls on the way to their nocturnal roosts.

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Assessing Southern Flying Squirrel, *Glaucomys volans*, Habitat Selection with Kernel Home Range Estimation and GIS

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Information on habitat selection behavior is vital to effective conservation and management of native terrestrial fauna, particularly in disturbed, fragmented habitats. Application of the kernel probability density estimation method to the description of animal home ranges, coupled with the mapping and analytical capabilities available in geographic information systems, allow researchers to gain a degree of insight into species' habitat use that has not previously been possible. This paper provides examples of habitat selection analyses performed using home range contours produced in the program KERNELHR and input into the Geographic Resources Analysis Support System (GRASS) where home range contours were overlain on habitat maps. Data for the examples were taken from a study of the Southern Flying Squirrel (*Glaucomys volans*) in fragmented forests in Arkansas, where flying squirrels were tracked by radiotelemetry on five study areas during spring and summer 1994–1996. However, the methods described here may also be applied similarly to other terrestrial vertebrates.

Key Words: kernel, KERNELHR, geographic information system, GRASS, home range, habitat selection, Arkansas.

Many native species of wildlife are being affected by habitat alteration. Effective conservation management requires information on a species' response to habitat disturbance and fragmentation. The lack of data on the effects of anthropogenic and natural disturbances on wildlife has prompted many ecologists to stress the need for autecological research in fragmented habitats (Simberloff and Abele 1982; McCoy 1983; Wilcove et al. 1986; Zimmerman and Bierregaard 1986). Recent advances in home range estimation techniques and geographic information system (GIS) technology have made new tools available to researchers seeking to better understand wildlife habitat requirements. Application of the kernel density estimator to animal home range description (Worton 1989; Worton 1995; Seaman and Powell 1996) provides a useful complement to the analysis and mapping capabilities of a geographic information system (GIS). Used together these technologies allow a more detailed and intensive examination of habitat selection than has previously been possible.

The kernel density estimator has several characteristics which make it attractive as a tool for analyzing animal location data: it is a nonparametric method applicable to multimodal distributional data, it produces a probability density estimate, and it is unaffected by grid size (Seaman and Powell 1996; Hansteen et al. 1997). However, only recently has the kernel method been used to describe home ranges (Worton 1987, 1989; Naef-Daenzer 1993; Seaman 1993; Worton 1995; Seaman and Powell 1996). The program used in this paper, KERNELHR, was first presented in the literature in 1998 (Seaman et al. 1998).

The fixed kernel home range estimator using least squares cross validation (LSCV) selection of bandwidth "h" has been shown through simulations to produce the most accurate home range estimates among five nonparametric methods, including the harmonic mean (Seaman and Powell 1996). Location data are used in the kernel method to produce an estimate of the subject animal's utilization distribution (UD, Van Winkle 1975). The UD estimates proportional usage of different areas in the home range. With a GIS, the UD can be overlain on a map of habitat types to analyze habitat use within the home range (Johnson's [1980] third-order selection) and selection in placement of the home range within a larger available area (Johnson's [1980] second-order selection).

This paper illustrates the use of the DOS-based kernel home range estimation program, KERNELHR (Seaman et al. 1998) in conjunction with the UNIX-based GIS software GRASS (Geographic Resources Analysis Support System, U.S. Army Corps of Engineers 1993) to analyze home range and habitat selection patterns. Data for examples are drawn from a study of Southern Flying Squirrel (*Glaucomys volans*) populations in managed forests (Taulman 1997). Since researchers continue to use polygon methods to describe animal home ranges (Linn and Key 1996; Stone et al. 1997) and to analyze habitat selection behaviors (Bendel and Gates 1987; Kamler and Gipson 2000), habitat selection analyses performed using the 95% minimum convex polygon (MCP, Michener 1979) and modified minimum area methods (concave polygon, Harvey and Barbour 1965) are provided for comparison.

Study Areas

A total of 94 Southern Flying Squirrels were fitted with radiotransmitter collars and tracked on five study areas in the Ouachita National Forest (ONF) of Arkansas ($34^{\circ}22'30''$ – 35° N, $93^{\circ}22'30''$ – $93^{\circ}45'$ W) during spring and summer 1994–1996. All core study areas where squirrels were captured in nest boxes were about 15 ha in area. Forest stands were composed of mature pine and hardwood overstory trees. Three of the stands (I, II, and III) were in a relatively old-growth condition where Shortleaf Pine (*Pinus echinata*) basal area (BA) at breast height ranged from 13.8–25.3 m²/ha, hardwood BA was 4.6–11.5 m²/ha, age of overstory trees was > 70 years, and stand aspect was generally south facing. The remaining two stands had been subjected to partial harvest the summer prior to initiation of this study. One was a pine-hardwood shelterwood harvest (IV) which retained 49–99 overstory pines and hardwoods per ha (6.9–9.2 m²/ha, of which 1.1–3.4 m²/ha were hardwoods). The other was a pine-hardwood seedtree harvest (V) which left 25–37 overstory trees per ha (2.3–4.6 m²/ha, of which 1.1–2.3 m²/ha were hardwoods).

Methods

Habitat description and mapping

Habitat types on and around each core stand were categorized and described using a set of 22 vegetative variables measured on multiple 400 m² macroplots. Variables represented shrub-layer and understory vegetative density, lower and upper mid-story tree densities, and overstory tree densities (Taulman et al. 1998). Quantitative comparisons of variables among different habitat types at each study area and among similar habitats at different study areas were used to validate habitat designations (Taulman et al. 1998). Habitat boundaries were digitized from aerial photos into GRASS, where raster maps were created. Differentially corrected global positioning system (GPS, Basic Plus and Geo-Explorer receivers, Trimble Company, Sunnyvale, California, USA) fixes of prominent landscape features and habitat edges (30–60 on each study area) were used register aerial photos and to edit and improve the accuracy of maps.

Radiotelemetry

Flying squirrels were captured during nest box surveys in March 1994–1996 and were fitted with radiotransmitter collars. Nest boxes were closed after the March survey and remained closed during telemetry activities. We located radiocollared animals by tracking on foot with a Wildlife Materials TRX-1000S receiver and an A 148-3S 2-meter FM yagi hand-held antenna (Cushcraft Corporation, Manchester, New Hampshire, USA). We began at dark, tracking an individual until either directly under the arboreal animal or in view of the squirrel

on a tree trunk or on the ground. When a GPS receiver was available, direct measurement of location coordinates was taken at the site. Otherwise, an assistant marked the position of the nearest site on which a GPS fix was known, the azimuth to that site was determined by the researcher at the squirrel position, and the distance was measured with a string hip chain. Universal Transverse Mercator coordinates were later computed trigonometrically for each telemetry location. Data collection continued for 6–8 hours; starting times were staggered to alternately include post-sunset and pre-sunrise activity patterns.

Squirrels were tracked in different order each night; normally one to two locations were obtained on each individual on a study area during a nightly shift, according to the suggested procedure of Swihart and Slade (1985a). The importance of independent data points for home range analysis is not unanimously agreed upon (Swihart and Slade 1985a; Andersen and Rongstad 1989; Reynolds and Laundre 1990; Minta 1992; Swihart and Slade 1997). Swihart and Slade (1988) described time to independence (TTI) as “the minimum time interval over which an animal could occur, in a probabilistic sense, anywhere in its home range”, and as “the time necessary for an animal to traverse its home range” (Swihart and Slade 1985b). They found that body mass in hunter species (those which utilized fruits, seeds, or mobile prey) was related to rate of home range use according to the formula $TTI \text{ in min} = 195 M^{0.49}$, M = mass in kg (Swihart and Slade 1988). Using the average mass of all adult squirrels encountered in 1993 (74 g) with the TTI formula for hunter species resulted in a calculated TTI estimate of 54 min for *G. volans*. We thus decided initially to maintain a temporal separation of at least one hour between successive locations on each animal during 1994 and 1995. This is double the minimum TTI considered sufficient for Southern Flying Squirrels by Fridell and Litvaitis (1991). In 1996, the minimum time interval between fixes was increased to two hours to observe whether statistical independence of locations would be thus improved. All sets of telemetry locations were examined with the three tests of independence (t^2/r^2 [Schoener 1981; Swihart and Slade 1985b]; Ψ [psi, Swihart and Slade 1985a]; and γ [gamma, Swihart and Slade 1986]) included in the computer program HOME RANGE (Ackerman et al. 1990).

Kernel home range calculation

Description of the kernel density estimation method as applied to animal home ranges (and comparisons with other common home range estimation methods) is given elsewhere (Silverman 1986; Seaman and Powell 1996; Seaman et al. 1998). The 95% fixed kernel density contour, computed using least squares cross validation selection of the smoothing parameter “h”, was used to describe home ranges in



FIGURE 1. Home range, core activity area, and available area contours for a single adult female Southern Flying Squirrel on study area IV in 1995. The contour data were computed in the KERNELHR home range program, then input into GRASS, where maps of habitats had been digitized from aerial photos. Fixed kernel 95% home range and core contours are shown, calculated using least squares cross validation procedures for selection of the smoothing parameter "h", and limiting "h" to the range 0.25–1.0 (as suggested by Seaman 1993). The 99% contour was computed from the same location data set, selecting the 99% level and using the "reference" smoothing parameter optimized by the program KERNELHR for bivariate normal data; it is used as an estimation of the habitats available for the placement of the home range.

this study. We limited the program's selection range for "h" to 0.25–1.0 times the reference value, as suggested by Seaman (1993). We follow Burt's (1940) definition of home range as "that area traversed by the individual during its normal activities of food gathering, mating, and caring for young . . ." As computed by the program KERNELHR, home ranges in this study comprise the smallest area containing 95% of the utilization distribution, as suggested by Seaman and Powell (1996). The core activity area computed by KERNELHR is that area enclosed by a contour within which locations are closer together than would be expected under the assumption of a uniform use of the home range area (Worton 1987), commonly from 60–75% of the utilization distribution.

Previous studies of habitat selection have presented what sometimes seem to be rather arbitrary and inconsistent methods for estimating available areas for habitat selection analyses (Neu et al. 1974; Byers et al. 1984; Rolley and Warde 1985; Gese et al. 1988). The accurate estimation of available habitats is essential to a valid habitat selection analysis which compares used and available areas (Johnson 1980; Porter and Church 1987). In order to arrive at a systematic method for estimating available area for an animal's placement of its home range, we used each animal's location data set to create a 99% contour using the "reference" h smoothing parameter value (without least squares cross validation), which is appropriate for bivariate normal data (Silverman 1986; Worton 1995; Seaman and Powell 1996). This contour is positively biased for multimodal, nonnormal data, typical of animal utilization distributions

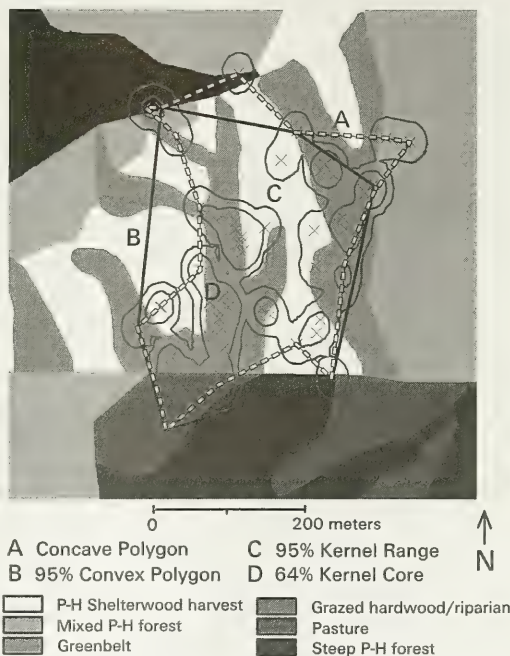


FIGURE 2. A comparison of the utilization distribution shapes and areas of habitats enclosed in home ranges estimated using the fixed kernel method with least squares cross validation selection of the smoothing parameter (program KERNELHR, Seaman and Powell 1995) to compute the 95% (C) and core activity area contours (D), the 95% minimum convex polygon (B, Michener's [1979] method in program HOME RANGE, Ackerman et al. 1990), and the modified minimum area method (A, Harvey and Barbour's [1965] method in program Telem88, Coleman and Jones 1988). All contours were computed using the same location data set from the adult female squirrel depicted in Figure 1. The 69 locations used to compute these ranges are denoted by Xs.

TABLE 1. Mean 95% kernel home range areas (with 1 standard error) for male and female Southern Flying squirrels on five study areas, computed with the program KERNELHR (Seaman et al. 1998). Study areas I, II, and III were mature pine-hardwood forest study areas, IV was a shelterwood harvest study area, and V was a seedtree harvest study area. Data were collected on study areas I and V in 1994, II in 1994 and 1995, III in 1995, and IV in 1995 and 1996. For comparison, home range areas computed with the 95% minimum convex polygon (MCP) and modified minimum area (concave polygon) methods are also given.

Study area	Gender	N	Mean locations	Mean time between observations (hr)	Inclusive dates	Mean (SE) 95% Kernel area (ha) ¹	Mean (SE) 95% MCP area (ha) ²	Mean (SE) concave polygon area (ha) ³
I	M	2	45.5	53.0	4/16 - 8/23, 1994	14.3	21.56	11.45
	F	6	47.3	55.9	3/23 - 8/23, 1994	6.43 (1.57)	5.08 (1.06)	3.27 (0.52)
II	M	6	47.9	49.8	4/12 - 8/18, 1994 and 1995	19.09 (5.65)	24.58 (8.45)	13.04 (3.57)
	F	8	57.5	42.4	4/12 - 8/19, 1994 and 1995	6.09 (1.87)	11.24 (5.59)	4.98 (1.56)
III	M	3	36.3	21.5	5/3 - 8/8, 1995	44.00 (15.16)	46.23 (11.60)	22.33 (8.90)
	F	2	60.5	36.0	4/23 - 8/8, 1995	6.04	4.62	5.41
IV	M	5	75.4	21.9	3/27 - 6/19, 1995 and 1996	4.80 (0.82)	5.84 (0.92)	3.96 (0.74)
	F	9	64.9	32.8	3/27 - 8/4, 1995 and 1996	5.57 (0.81)	6.97 (1.07)	5.30 (0.99)
V	M	2	38.0	80.4	3/28 - 7/23, 1994	2.76	3.26	1.85
	F	1	41.0	65.8	3/21 - 6/8, 1994	3.38	7.50	2.85

¹Seaman and Powell (1996), Seaman et al. (1998).

²Michener (1979)

³Harvey and Barbour (1965).

(Seaman and Powell 1996). It also includes areas beyond the observed locations, a "buffer zone" of habitats in which the animal has not been observed (Figure 1). Thus, available area was calculated consistently among all animals, but separately for each animal, and reflected known individual habitat use patterns.

Only location data sets which reached a plateau on a location-area curve (Cain 1938; Odum and Kuenzler 1955) were used for home range and habitat selection analyses (50 of 94). Worton (1987) advised that a minimum of about 30 locations are needed for nonparametric home range estimators; therefore, only the 42 data sets with ≥ 30 locations,

were used in comparisons of home range size among study areas. However, available area and home range should be biased proportionately for each individual, and habitat selection analyses are considered valid for each animal whose location data showed a plateau on the location-area curve, including the eight with fewer than 30 (14–29) total locations.

Home ranges of all 50 squirrels were also estimated using the 95% minimum convex polygon method and the modified minimum area method (Figure 2).

Habitat selection analysis

We analyzed two levels of habitat selection for squirrels during their nightly activities [Johnson's

TABLE 2. A sample of nesting habitat selection results on study area II in 1995. Available area of different habitat types (m_i), proportion of available areas of each habitat type ($\pi_i = m_i / m_+$), number of diurnal nest trees in each type (u_i), used proportion of nest trees in each habitat ($o_i = u_i / u_+$), habitat selection ratios ($\hat{w}_i = o_i / \pi_i$), and Bonferroni confidence intervals (after Manly et al. 1993). Each interval represents a 99% confidence limit, total confidence for all intervals approximately 95% (confidence intervals for habitats with less than five trees not conclusive). A + indicates significant selection for a habitat type, - against. MAT P-H = mature pine-hardwood forest, YNG PLA = young pine plantation (< 15 years old), IMM PLA = immature pine plantation (15 - 40 years old), STP P-H = steep pine-hardwood forest, GB = greenbelt.

Habitat type	Area in home ranges (ha) (m_i)	Available proportion (π_i)	Diurnal nests (u_i)	Used proportion (o_i)	Selection ratio (\hat{w}_i)	Standard error	Lower C.I.	Upper C.I.
MAT P-H	108.38	0.758	49	0.875	1.154	0.034	1.07	1.24 +
YNG PLA	13.90	0.097	1	0.018	0.184	0.002	0.18	0.19 -
IMM PLA	1.99	0.014	0	0	0	0		-
STP P-H	3.46	0.024	0	0	0	0		-
GB	15.22	0.106	6	0.107	1.006	0.004	0.99	1.02
Total	142.95	1.000	56	1.00				

TABLE 3. A sample of nesting habitat selection results on a harvested stand, study area IV, in 1995. Available area of different habitat types (m_i), proportion of available areas of each habitat type ($\pi_i = m_i / m_+$), number of diurnal nest trees in each type (u_i), used proportion of nest trees in each habitat ($o_i = u_i / u_+$), habitat selection ratios ($\hat{w}_i = o_i / \pi_i$), and Bonferroni confidence intervals (after Manly et al. 1993). Available area for nesting determined by summing all habitat areas from squirrel home ranges and combining total number of diurnal nest trees. It is assumed that squirrels are able to independently select nesting sites in areas overlapping the ranges of other squirrels; nesting aggregations common for *Glaucomys volans* support this assumption. Each interval represents a 99% confidence limit, total confidence for all intervals approximately 95% (confidence intervals for habitats with less than five trees not conclusive). A + indicates significant selection for a habitat type, - against. GB = greenbelt, STP P-H = steep pine-hardwood forest, P-H SW = pine-hardwood shelterwood harvest, MIX P-H = uneven aged pine-hardwood forest, HDW RIP = private, grazed hardwood riparian zone.

Habitat type	Area in home ranges (ha) (m_i)	Available proportion (π_i)	Diurnal nests (u_i)	Used proportion (o_i)	Selection ratio (\hat{w}_i)	Standard error	Lower C.I.	Upper C.I.
GB	14.36	0.400	23	0.511	1.276	0.030	1.198	1.355 +
STP H-P	2.85	0.079	1	0.022	0.280	0.002	0.275	0.284 -
P-H SW	8.26	0.230	4	0.089	0.386	0.010	0.360	0.412 -
MIX P-H	8.82	0.246	16	0.356	1.446	0.018	1.399	1.492 +
HDW RIP	1.57	0.044	1	0.022	0.508	0.001	0.505	0.510 -
Total	35.86	1.00	45	1.00				

(1980) second and third order selection]: home range placement within the available region, and use of habitats within the home range, respectively. Selection ratios represented: (1) the proportion of a habitat in the home range vs. the proportion of that habitat in the available area; and (2) the percentage of locations in each habitat within the 95% home range vs. the proportion of that habitat type available in the home range. Selection ratios were calculated for each habitat category for each squirrel using that habitat. At each study area mean selection ratios were computed for each habitat type using all individual selection ratios. Bonferroni 95% confidence intervals (Manly et al. 1993) were computed for selection ratio means; an entire 95% confidence interval > 1 was interpreted as indicating significant selection for a particular habitat type; < 1 indicated significant avoidance of a habitat type.

To evaluate diurnal nest-site habitat selection we defined available habitat as the area enclosed by the 95% kernel home range contours for all squirrels on a study area. Percentages of all nesting trees on a study area in each habitat type during a given year were compared with summed proportions of habitat areas within 95% kernel home range contours for all squirrels on a study area. This method acknowledges that home ranges may overlap and assumes that squirrels are able to independently select nesting sites within areas of overlap. Communal nesting, commonly seen in Southern Flying Squirrels (Muall 1974; Taulman et al. 1998), confirms that nesting sites are not mutually exclusive among individuals. The combined number of nest trees within all home ranges is thus proportional to available habitats in those ranges summed for all squirrels.

Since we know of no logical and defensible paradigm for estimating available area for the place-

ment of a home range described by the polygon method, we did not attempt a second-order habitat selection analysis using MCP or concave polygon range estimators. We did perform the third-order analysis of use of habitats within the polygon home ranges, comparing the percentage of locations in a habitat type in the home range with the proportion of that habitat area within the range polygon.

Results

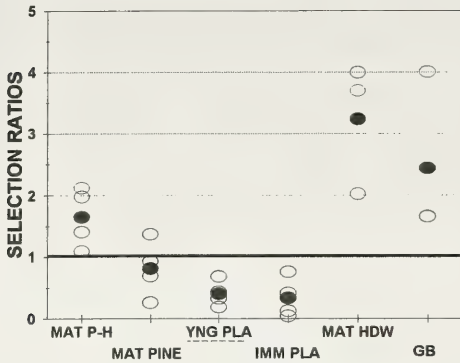
Independence of telemetry locations

In tests of the independence of location data sets, 36% percent of data sets in 1994 and 1995 showed no autocorrelation, 50% failed at least one of the significance tests, and 14% of sets failed all three tests. Examining data from 1996, with a two-hour minimum time between observations, 38% passed all tests, 38% failed at least one, and 25% failed all three. The differences in observed statistical independence of data sets under the two different estimated TTI were significant (Chi-square = 11.63, d.f. = 2, $p = 0.003$), but inconclusive. Compared with the one-hour TTI in 1994 and 1995, more data sets passed one or two independence tests, but more data sets failed all three tests, under the two-hour minimum TTI in 1996.

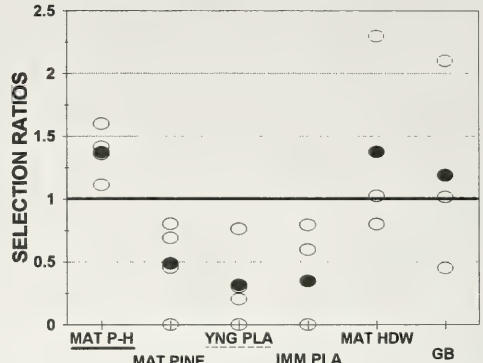
Home ranges

Kernel 95% home range areas of males among all three years were marginally larger than those for females (Mann-Whitney $U = 153.5$, $p = 0.055$). Kernel range areas for males were different among years 1994 to 1996 (Kruskal-Wallis $H = 6.44$, $p = 0.04$), but not among study areas (Table 1). The multiple comparisons test (Siegel and Castellan 1988) indicated that male ranges were significantly larger in 1995 compared with 1996, reflecting large ranges

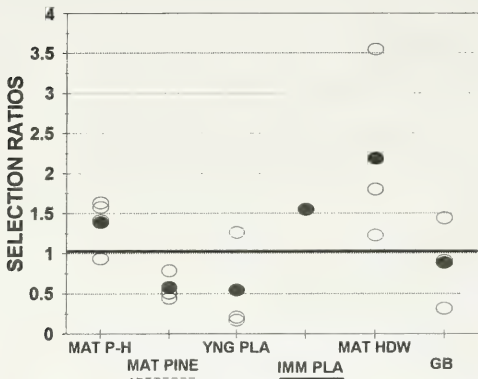
A. 95% kernel home range areas in available region



B. Telemetry locations in 95% kernel home range



C. Telemetry location in concave polygon home range



D. Telemetry locations in 95% convex polygon range

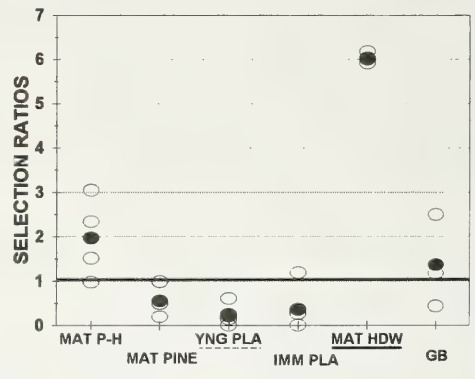


FIGURE 3. A sample of habitat selection results for nightly activities of five squirrels on an unmanaged mature forest stand. Selection ratios are shown for study area III in 1995. A. Proportions of habitats in the 95% kernel home range divided by proportions of habitats within the available region. B. Proportions of telemetry locations in each habitat type divided by habitat area proportions in the 95% kernel home range. C. Proportions of telemetry locations divided by habitat proportions in the concave polygon home range estimate. D. Proportions of telemetry locations divided by habitat proportions in the 95% minimum convex polygon home range estimate. Selection ratios equal to 1 indicate no selection, > 1 indicate selection for a habitat type, < 1 against that habitat type. Mean selection ratios for each habitat type denoted by filled black ovals. Significant selection for a habitat type indicated by solid underscore, significant selection against a habitat shown with a dashed line underscore. Significance of selection against or for each habitat determined by 95% Bonferroni confidence intervals falling completely below or above 1, respectively. MAT P-H = mature pine-hardwood forest, MAT PINE = mature pine plantation, YNG PLA = young pine plantation (< 15 years old), IMM PLA = immature pine plantation (15–40 years old), MAT HDW = mature mixed hardwood forest, GB = greenbelt, mature forest riparian strips through harvested habitat.

on two study areas sampled in 1995 but not in 1996. Kernel 95% range areas of female squirrels did not differ among years or among the five study areas (Table 1). Ranges on study area III were largest and those on study area V were the smallest.

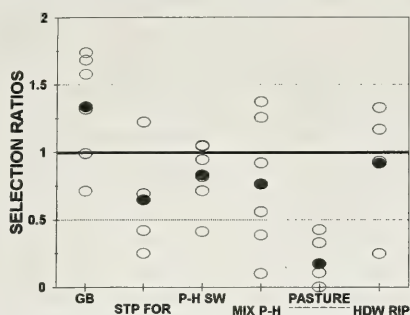
Both the MCP and minimum area methods produced range estimates which enclosed proportionately large areas where radiocollared squirrels had not been observed (Figure 2). The size of the polygon ranges is generally larger than the kernel range estimate due to the inclusion of unused habitats. The shape of ranges created by both polygon methods does not reflect intensity of use of areas

within the home range, as does the kernel function (Figure 2).

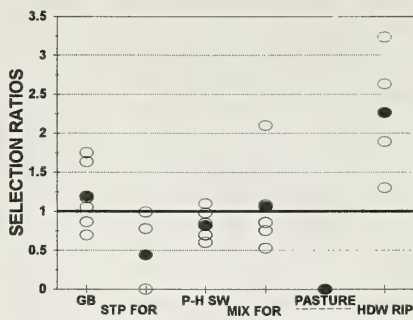
Habitat selection patterns

Habitat selection analyses were performed for squirrels on study areas I (8), V (5), and II (6) in 1994; II (12), III (5), and IV (6) in 1995; and IV (8) in 1996. As illustrative examples, overall habitat selection results for nightly activity periods are presented for study areas III and IV in 1995 (Figures 3 and 4, respectively, including selection analyses using polygon methods for range estimation). Diurnal nesting habitat selection results are shown

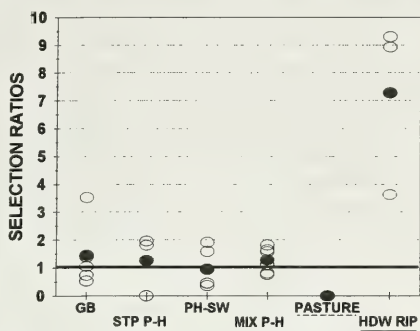
A. 95% kernel home range areas in available region



B. Telemetry locations in 95% kernel home range



C. Telemetry locations in concave polygon home range



D. Telemetry locations in 95% convex polygon home range

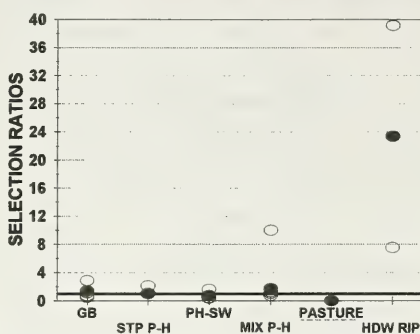


FIGURE 4. A sample of habitat selection results nightly activities of five squirrels on study area IV in 1995. A. Proportions of habitats in the 95% kernel home range divided by proportions of habitats within the available region. B. Proportions of telemetry locations divided by habitat proportions in the 95% kernel home range. C. Proportions of telemetry locations divided by habitat proportions in the concave polygon home range estimate. D. Proportions of telemetry locations divided by habitat proportions in the 95% minimum convex polygon home range estimate. For interpretation, see Figure 3 caption. GB = greenbelt, mature forest riparian strips through harvested habitat, STP FOR = steep mixed pine-hardwood forest, P-H SW = pine-hardwood shelterwood harvest area, MIX P-H = mixed aged pine-hardwood forest, PASTURE = grazed pasture on private land, HDW RIP = mature hardwood riparian forest on private land.

for study areas II and IV in 1995 (Tables 2 and 3, respectively).

Mean selection ratios for squirrels in individual habitat types on each study area showed selectivity in the placement of the home range within the available habitats, in use of habitats within the home range, and in nest site location. Unmanaged mature pine-hardwood and hardwood forests were selected for nesting and foraging where available (Figure 3); on harvested stands protected forests in riparian greenbelt (GB) zones were highly selected for nesting, and GB and adjacent mature forests were used for foraging (Figure 4, Table 3). During nightly activity periods, some male squirrels made long forays to distant hardwood stands on mature pine-hardwood study areas in which both densities of overstory hardwoods, and actual mast production measured during fall 1994 and 1995 surveys, were low. Home range shapes showed elongation where valued habitats were narrow or widely separated. Home ranges overlain on habitat

maps, and habitat selection ratio results, showed that young and immature pine plantations were generally avoided, except for infrequent forays to exploit soft mast resources at study areas with low hard mast availability in mature forests. Corridors of mature pines and hardwoods along riparian zones were used to travel through pine plantations.

Due to the lack of a correlation between the area of a habitat type in an individual squirrel's polygon range and the intensity of use of that habitat by the squirrel, habitat selection ratios calculated using 95% MCP and modified minimum area (concave polygon) range estimators gave results which sometimes showed significant habitat selection for a type that was actually avoided by squirrels (such as the significant selection indicated for immature pine plantation habitat in the concave polygon analysis at study area III, Figure 3). Such spurious results did not occur with selection results from the kernel range estimation method (Figures 3 and 4).

Discussion

Lack of statistical independence in sequential locations may occur due to several factors: (1) a range shift during data collection, (2) a coincidence of data collection times with natural cyclic patterns of the subject animal's behavior, and (3) nonrandom use of area within the home range (Swihart and Slade 1985b). We suggest that the lack of independence in some data sets under each of the minimum TTIs (one or two hours) resulted from squirrels using their ranges in a nonrandom manner, rather than an insufficient TTI.

Both types of polygon range estimates used in this paper often enclose large areas receiving little or no actual use by the animal in question (Worton 1987). A typical result is a corresponding reduction in the proportions of high-use habitats within the range, which are considered available areas and compared with the proportions of animal locations. Thus, very high selection ratios for those high-use habitats can be obtained, compared with selection ratios computed using the kernel home range method (Figures 2, 3, and 4). An animal's use of smaller habitat patches at the periphery of its range can also produce highly variable, often inflated, selection ratios for those habitats under polygon range analyses, due to the inability of perimeter point methods to weight the range and add area to peripheral sections containing clusters of locations (see Figure 2). These differences in selection ratio results between kernel and polygon methods were less pronounced in analyses of nesting habitat than those seen in analyses of overall use (Tables 3 and 4).

Researchers continue to use polygon methods, such as the minimum convex polygon and modified minimum area method, to describe animal home ranges (Linn and Key 1996; Stone et al. 1997) and to analyze habitat selection behaviors (Bendel and Gates 1987; Smith et al. 1999). However, polygon home range estimates give no information on the relative intensity of use of habitats within the home range, and are therefore of little value in examining habitat use patterns. Polygon home range methods also provide no logical method for defining an available area which the researcher can use to investigate habitat selection in an animal's placement of its home range.

The kernel home range estimation method provides additional information over polygon methods about individual variation in habitat use and avoids the problems associated with the harmonic mean method, such as the lack of a probability density estimate, sensitivity to grid cell size, and inconsistent results depending upon distance of observations from grid intersections (Worton 1989). In addition, the kernel home range estimation method may be used to create a contour from a location data set which encompasses unused habitats surrounding an

animal's home range. This estimate of available area for the placement of the home range, a third-order habitat selection analysis, is unique for each individual and is based on that animal's documented movement patterns. Importing range boundaries created with the kernel home range method into a GIS containing maps of study area habitats allows the attainment of a level of precision in the analysis of habitat use patterns that has not been possible with other techniques. Analyses of habitats used compared with those available are accomplished in the GIS, and resulting habitat selection ratios may be more specifically defined through the creation of Bonferroni confidence intervals, as described by Manly et al. (1993). Habitat selection analysis methods presented here may be used effectively on any terrestrial vertebrate for which a sufficiently large location data set can be acquired (one containing > 30 locations and showing a plateau on a location/area curve).

Previous investigators using observational techniques, live trapping, and telemetry with polygon home range estimation methods, have concluded that Southern Flying Squirrels are forest habitat generalists (Muul 1974; Healy and Brooks 1988; Stone et al. 1997). The present investigation of habitat selection by 50 flying squirrels at five study areas, employing the complimentary use of kernel home range estimator and a GIS, revealed that squirrels were selective in habitats used during both their nocturnal activity periods and for natural diurnal nesting sites.

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Age Structure of Eastern White Pine, *Pinus strobus* L., at its Northern Distribution Limit in Québec

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Stand age structures of Eastern White Pine (*Pinus strobus* L.) were analysed on three sites with different fire histories (last fire 1760, 1825 and 1941, respectively) in Québec to assess whether Eastern White Pine is regenerating or not at its northern limit. Previous paleo-botanical findings suggest that this species once extended ca 100 km further north than the present distribution limit in Québec. All three sites (dry habitats) represented vital populations where the individuals were established after the most recent fire. The results suggest that the relative lack of dry and/or disturbed sites in combination with a more severe fire regime that characterizes the northern lowlands, may explain why white pine expansion is restricted northwards.

Key Words: Eastern White Pine, *Pinus strobus*, fire, boreal forest, tree regeneration, Québec.

Climate is generally considered to be a main factor controlling northern limits of plants (e.g., Woodward 1992; Kullman 1995). However, studies have also reported that other factors such as disturbance, soil conditions, and competition are important for distribution, regeneration and stand dynamics (cf. Currie and Paquin 1987; Bradshaw 1993; Engelmark 1999). Studies on North American pine species, have suggested that fire disturbance is important in controlling the northern distribution, thus indicating that climate per se is not always a limiting factor (Bergeron and Gagnon 1987; Despons and Payette 1992; Flannigan and Woodward 1994; Meilleur et al. 1997). Jack Pine (*Pinus banksiana*) has serotinous cones, and is regenerating successfully at its northern limit (Despons and Payette 1992; Johnson and Gutsell 1993). Red Pine (*P. resinosa*) (Bergeron and Brisson 1990, 1994; Engstrom and Mann 1991; Flannigan 1993; Flannigan and Woodward 1994; Flannigan and Bergeron 1998), and Pitch Pine (*P. rigida*) (Meilleur et al. 1997) are also reported to recruit frequently at their respective northern limits (see also Vander Kloet 1973). Studies on Eastern White Pine (*P. strobus*) at its northern limit are however scanty (cf., Holla and Knowles 1988), although its regeneration dynamics further south has been discussed (e.g., Heinzelman 1973, 1981; Quinby 1991; Abrams et al. 1995).

We propose that the present Eastern White Pine distribution is not limited directly by climate alone, but possibly also by other environmental factors. To assess whether *Pinus strobus* is regenerating or not at its present northern distribution limit, age structure analyses were performed in three stands with differ-

ent fire histories at its northern limit in Québec, eastern Canada.

Study area

The study was carried out at the present northern limit of *Pinus strobus*, in the Lake Abitibi-region in NW Québec (Figure 1). The area is located in the southern boreal forest within the Missinaibi/Cabonga forest section (Rowe 1972), where mature forests are dominated by *Abies balsamea* with *Picea mariana*, *P. glauca* and *Betula papyrifera* as co-dominants. Depending on the time since the last disturbance, the type and severity of the disturbance, varying proportions of *Pinus banksiana*, *P. resinosa*, *P. strobus*, *Picea mariana* and *Thuja occidentalis* are found on xeric sites (Bergeron and Dubuc 1989; Bergeron 1991). The area belongs to the Northern Clay belt of Québec and Ontario (Vincent and Hardy 1977). The mean annual temperature and precipitation are 0.6°C and 823 mm, respectively, and the average annual frost-free period is 64 days (Anonymus 1982).

Three stands with elapsed time since the last fire were sampled, viz. fire years were 1760, 1825 and 1941 (hence the stands are named "S17", "S18" and "S19", respectively). These fires were of lethal, crown-destructing character (Clayden and Bouchard 1983; Bergeron 1991). The stands were located on elevated, dry sites with shallow till, and contained a mixture of *Pinus strobus* and *P. banksiana* as dominant trees. The Eastern White Pine individuals were generally vigorous, young individuals with long annual shoots and mature trees with large cone crops (Figure 2).

Field layer dominants in stand S17 and S18 were *Kalmia angustifolia*, *Vaccinium angustifolium*, *V.*

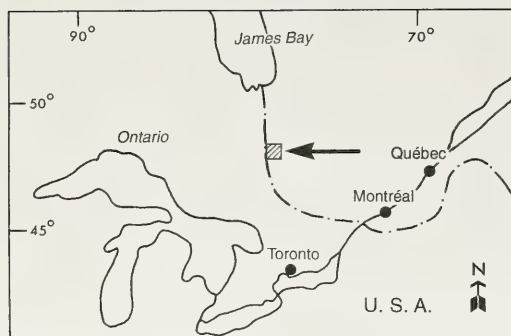


FIGURE 1. Map showing the location of the Lake Abitibi area, which represents the present northern limit of *Pinus strobus* in eastern Canada.

myrtilloides and *Chamaedaphne calyculata*, and *Cladonia* spp. dominated in the bottom layer, while *V. angustifolium*, *V. myrtilloides* and *Ledum groenlandicum* dominated in S19. Exposed rock was present to about 25% at all sites.

Methods

In July 1994, one sample plot within each stand was selected for data collection. The aim to sample a minimum of 130 pines in each stand resulted in three different plot sizes, viz. S17: 200 × 300 m ($n = 176$);

S18: 70 × 175 m ($n = 138$); and S19: 70 × 110 m ($n = 150$). Within the sample plots all *Pinus strobus* individuals with a basal stem diameter < 4 cm were age-determined by counting branch nodes. A sample of small trees ($n = 25$) was cut to verify congruence between number of branch nodes and tree rings ($R^2 = 0.92$). Trees with a basal stem diameter > 4 cm were cored at the root-neck for age determinations. The cores were dried, planed and the annual rings were counted using a stereo-microscope (6–50×). The annual rings were easily determined due to high growth rate, and the tree datings could thus be done with high accuracy.

Results

All three sites presented vital and continuously recruiting white pine populations. The 464 sampled pines were established between 1790 and 1993 (Figure 3). The separate stand age structures exhibit postfire regeneration, although not until the study year (1994) was the surviving regeneration cohort discernible after the 1760-fire in stand S17. This may be related to the fact that old Eastern White Pines (> 200 yr) often suffer from fungal stem rot and are prone to blow down (Holla and Knowles 1988; Webb 1989; Abrams et al. 1995). For S18, an Eastern White Pine cohort was recorded after the 1825-fire. Stand S19 shows a significant regeneration increase after the fire in 1941.



FIGURE 2. A view from S19 showing *Pinus strobus* individuals, about 40-yr-old.

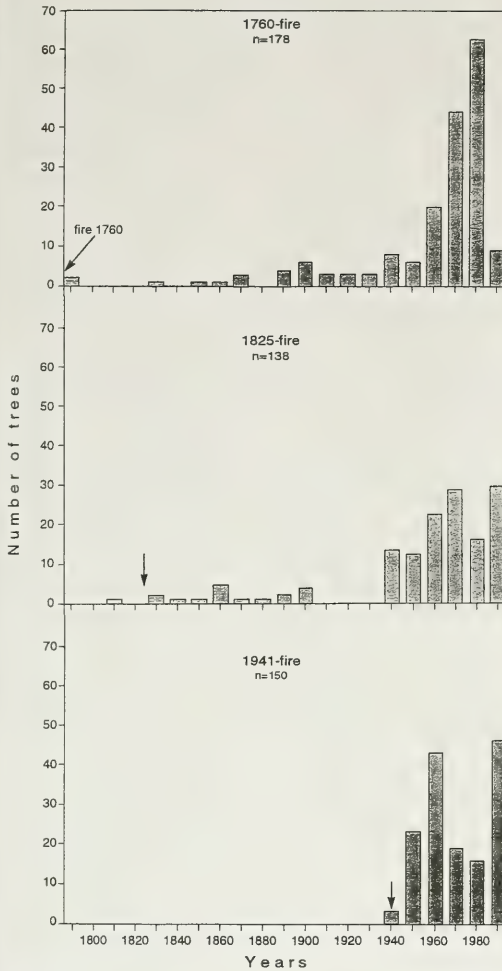


FIGURE 3. Age structures for the three sampled *Pinus strobus* stands, S17 (top), S18 (middle), and S19 (bottom). Arrows indicate fire years.

Discussion

Successful Eastern White Pine regeneration has followed after the respective fires in all three stands. A comparable postfire age-distribution was found for Red Pine also at its northern limit in the same area (Bergeron and Gagnon 1987), a pattern which is indicative of broadly stable populations at the landscape level (Parker 1986; Engelmark et al. 1994). The pattern of postfire recruitment is also reported for Jack Pine (Despons and Payette 1992) and Pitch Pine (Meilleur et al. 1997) at their northern limits. This supports our idea that climate is not solely controlling the northern distribution limits of these pines.

Further, the multi-aged Eastern White Pine distribution found in this study is congruent with results

presented by Holla and Knowles (1988) at the Eastern White Pine limit in Ontario, corroborating that a continual recruitment is possible even without recent fire disturbance (>230 yr in this study), provided that small-scale gaps suitable for regeneration (e.g., wind-throws or open xeric outcrops) are available in the landscape (Quinby 1991). Germination is regarded to be most successful on bare soil or thin organic layers. In addition, many seed trees form the uppermost canopy and as Eastern White Pine has a relatively large seed production (Fowells 1965), seeds disseminate easily. Accordingly, in this study regeneration was successful within existing stands. But maybe the relative lack of dry habitats suitable for regeneration (e.g., rock outcrops) in the landscape of the Northern Clay Belt (cf. Clayden and Bouchard 1983), is partly limiting further Eastern White Pine expansion under present climate and disturbance regimes. This is, in part, contradicted by the greater northward expansion of Eastern White Pine in this area during the Holocene warming up to about 3000 yr BP, indicating that dry, suitable sites then were available (cf., Terasmae and Anderson 1970; Liu 1980).

Thus, under the presently low to moderately intense fire regimes, Eastern White Pine recruits well on dry habitats at its northern limit. With regard to the actual, continuously occurring regeneration, we suggest that further expansion is prevented by the prevailing high-intensity fire-regime north of the present Eastern White Pine distribution. This lethal fire-regime, characteristic to the north, instead favours conifers with serotinous cones, as Jack Pine (Despons and Payette 1992). We hypothesize therefore that in parallel to Jack, Red and Pitch pine, the northern limit of Eastern White Pine is fire-controlled, rather than climatically-controlled, and, finally, that these pine species respond specifically to different fire regimes.

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Diet of Wintering Bald Eagles, *Haliaeetus leucocephalus*, In New Brunswick

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The diet of wintering Bald Eagles (*Haliaeetus leucocephalus*) in New Brunswick was determined from 949 feeding observations, 1992–1999. White-tailed Deer (*Odocoileus virginianus*) accounted for 43% of the total occurrences, offal 30%, birds 16%, other mammals 8%, fish 3% and invertebrates < 1%. Thirty-five percent of the prey items were of aquatic origin. There were considerable dietary differences between inland and coastal feeding eagles. Avian prey (seabirds and waterfowl) were of greater importance to the coastal birds. Salmon offal consumption at aquaculture sites along the coast was significant. Over 70% of the dietary items taken by immature eagles were scavenged deer and offal. Some of the prey items consumed showed a marked seasonal variation. Almost 60% of all feeding occurrences in February and March involved deer. Both birds and fish decreased in importance from late fall to early spring. Immature eagles were found more commonly in mixed feeding groups than as solitary foragers. The risk of environmental contaminant exposure is likely greater for coastal wintering eagles that feed more heavily on aquatic organisms than for inland wintering birds.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, diet, feeding, New Brunswick.

New Brunswick has a small wintering Bald Eagle (*Haliaeetus leucocephalus*) population, numbering in the low hundreds, that has increased about five fold since the mid-1980s (Stocek, unpublished). Many birds feed and roost along the southwestern coastal area of the province, especially on marine islands in Passamaquoddy Bay. Scattered eagles are seen in river valleys and less frequently at other coastal locations. Banding records show that the wintering birds move back and forth between eastern Maine and southern New Brunswick; some occasionally migrate further south to other eastern states.

Wintering eagles are exposed to a variety of risks, including heavy metal and organochlorine contaminants such as mercury, PCBs and DDE. Elevated levels of mercury in aquatic biota in eastern Canada pose a risk to a high level predator such as the Bald Eagle (Mercury Team 1998), known to consume fish and water birds. Mercury levels in Common Loons (*Gavia immer*) in Atlantic Canada are among the highest in North America (Evers et al. 1998). These same contaminants appear to be limiting the reproductive capabilities of the Maine eagle population (Welch 1994; Wiemeyer et al. 1993). As these pollutants are apparently found in potential eagle prey in Maine (Todd 1979), it is reasonable to assume that a similar situation exists in nearby New Brunswick.

Contaminants accumulated from food consumed during winter and early spring may be critical for breeding eagles as some lipophilic compounds may be deposited in the eggs (Ewins and Andress 1995). Assessment of contaminant loads in these birds requires a knowledge of their wintering diet. Very little has been documented about foods of wintering

eagles in New Brunswick. Early work by Wright (1953) concerning eagles and breeding ducks dealt almost entirely with summer records but inferred a change of diet during the winter.

This paper describes the diet of wintering eagles as determined from direct feeding observations made throughout New Brunswick.

Methods

Observations of feeding Bald Eagles were collected during the winters of 1992–1999. A standardized check list was developed to record information on wintering eagles including date of feeding observation, location, number of eagles feeding at each site, identified food items, age of birds (adult or immature), and interactions with other birds or mammals at the feeding site. Only records with identified prey or food were used in analysis. Dietary items were identified to the highest taxon possible.

Feeding records were solicited from a variety of sources including personnel of the New Brunswick Department of Natural Resources and Energy, Canadian Wildlife Service, Ducks Unlimited, and New Brunswick Museum. Forest companies in the province were contacted as were fish and game clubs, naturalist clubs, and the general public (through newspaper and radio interviews). Personal observations by the author were also used.

A feeding observation or occurrence was defined as one eagle feeding on one prey or food item at a particular site on one day in October through April. Feeding referred to an eagle pursuing, catching, restraining, killing or consuming prey, and included carrion consumption. Unsuccessful pursuits (usually

involving water birds) were acceptable records if the intent appeared to be the capture of prey rather than scaring it away or supplanting it at a kill. Repeated sightings of eagles feeding for longer periods of time (day, weeks) on a single food item (such as a deer carcass) were not included in this study. Counting one item as many records (e.g., at one site over a period of days) would unrealistically increase carcass and offal results. Only one foraging occurrence per bird was compiled during any group feeding incidents on one food item. However, repeated sightings over an extended period of time (more than one day) were rarely reported on by observers.

Observations originated across New Brunswick (Figure 1). Most were near waterways (mostly frozen rivers) or coastal areas. Inland waters generally freeze over by November–December and remain that way into March–April. This limits fresh-water fishing opportunities for eagles, but holes in ice on lakes and rivers and open dam tailraces remain available for foraging there. Tidal rivers and open salt waters often remain ice-free. Feeding observations in northern New Brunswick were sparse corresponding to scarcity of wintering eagles there.

Results

A total of 949 feeding observations or occurrences of wintering Bald Eagles were recorded from 1992 to 1999. Among the dietary items consumed, White-tailed Deer* accounted for 43% of the total occurrences; offal, 30%; birds, 16%; other mammals, 8%; fish, 3% and invertebrates < 1% (Table 1). Identified prey included at least six species of fish, 19 of birds, 17 of mammals, one of invertebrates, and at least five kinds of offal (Appendix 1). In total, 35% of the prey items were of aquatic origin, including 95% of the birds (144 of 151 observations), and 21% of mammals other than deer (15 of 73). The importance of deer in the wintering eagle diet is especially evident in New Brunswick. Most deer were reportedly killed or crippled by Coyotes (*Canis latrans*), domestic or feral dogs (*Canis familiaris*), hunters, motor vehicles, trains, or starvation. Occasionally deer were driven onto river or lake ice where they succumbed and were fed upon by a variety of scavengers. Road killed deer carcasses often were collected by forest rangers and disposed of on a field or on ice where eagles had access to them. Offal represented a substantial component of the eagle diet. Herein, the term refers to animal carcasses or remains derived from the husbandry of birds (poultry), mammals (cattle, swine), or fish (aquaculture salmon) that were put out to attract scavengers such as the eagle.

The by-catch of commercial fishermen (occasionally left on the ice), carcasses of deer, moose and beaver (sometimes put out to attract predators), dead cattle on range, and road-killed small mammals were not considered offal.

Overall consumption of water birds by eagles included a variety of puddle and diving ducks, geese, cormorants, guillemots and loons. Gulls (mainly Herring and Great Black-backed), often captured in the air, represented over half (58%) of all the birds consumed. Although 27% of the avian prey were ducks and geese, they represented only four percent of the total feeding occurrences. The only terrestrial bird species recorded were Ruffed Grouse, Ring-necked Pheasant, Wild Turkey (stocked), Great Horned Owl, and Rock Dove.

Beached seals, porpoises and whales were the marine mammals recorded in the feeding observations. Other aquatic mammals noted were Muskrats, captured alive, and Beavers, scavenged from skinned carcasses put out by trappers. Wintering Bald Eagles were observed hunting with Herring Gulls (*Larus argentatus*) for Meadow Voles in a flooded meadow.

The only freshwater fish species identified as prey were the American Eel and the Atlantic Salmon. However, a variety of brackish and salt-water fish, often left on the ice by commercial fishermen, were also fed upon.

Only one occurrence of an eagle feeding on invertebrate prey was noted, that of an adult pulling out and consuming marine worms from a mud flat at low tide.

Live domestic animals taken as prey by wintering eagles included a dog, cat, rabbit, new born lamb, and ducks. Domestic rabbits were observed moving amid feeding eagles (to within 1.5 m of a bird) and were completely ignored. But at another time at the same coastal location an immature eagle unsuccessfully attacked a domestic rabbit in the yard of an observer.

Coastal feeding observations amounted to 28% of the total sightings (Table 1). There were some considerable dietary differences between inland and coastal areas of the province. Deer scavenging at inland sites involved over 60% of all observations there. Avian prey (mostly sea birds) assumed much greater importance in the diet of coastal eagles, over 40% of the items consumed. Waterfowl represented 16% of the 269 coastal feeding occurrences. Consumption of salmon offal at the aquaculture sites represented almost half of the coastal observations. Wild fish consumption at both coastal and inland locales seemed relatively unimportant to wintering eagles. Almost all fish taken along coastal areas were culls left by commercial fishermen. Coastal observers confirmed that fishing activity by wintering eagles was almost nil (R. Eldridge, personal communication).

Over 70% of the feeding observations for which

*Scientific names of prey items and breakdown of food categories are given in the Appendix.



FIGURE 1. General distribution of wintering Bald Eagle feeding observations, 1992-1999, New Brunswick. Many locations represent a number of feeding sites.

class was recorded were of adult eagles (Table 2). The importance of deer in the diet of both adults and immatures was evident. A notable difference in food utilization was the greater use of offal by immatures. In fact, 71% of the dietary items taken by the younger birds were scavenged deer and offal. Of 32 hunting attacks witnessed on coastal water birds, eight involved immature eagles.

There was a marked seasonal variation in some of the prey items consumed (Table 3). Scavenged deer constituted a substantial part of the diet in the colder

months and early spring. Almost 60% of all feeding occurrences in February and March involved deer. Both birds and fish decreased in importance as the seasons progressed. Small mammals were more available to foraging eagles in the early spring. Offal consumption was most evident in late fall and winter.

Less than one percent of the 949 feeding observations in New Brunswick were reported as stealing (from gulls, cormorants, seals, and other eagles). This is likely an underestimate. Without seeing an

TABLE 1. The occurrences (%) of food items utilized by wintering Bald Eagles in New Brunswick, 1992-1999, from direct feeding observations.

Food Item	Number of observations (%)		
	Coastal	Inland	Total
Fish	11 (4)	18 (3)	29 (3)
Bird	109 (41)	42 (6)	151 (16)
Deer	0 (0)	413 (61)	413 (43)
Other mammals	22 (8)	51 (7)	73 (8)
Offal	126 (47)	156 (23)	282 (30)
Invertebrate	1 (<1)	0 (0)	1 (<1)
Total	269	680	949 (100)

TABLE 2. The occurrences (%) of food items utilized by adult and immature wintering Bald Eagles in New Brunswick, 1992–1999, from direct feeding observations.

Food Item	Number of observations (%)	
	Adult	Immature
Fish	25 (6)	3 (2)
Bird	74 (17)	30 (19)
Deer	166 (39)	52 (32)
Other mammals	54 (13)	13 (8)
Offal	104 (25)	62 (39)
Invertebrate	1 (<1)	0 (0)
Total	424	160

entire feeding episode some observers may have missed this prelude to food acquisition, recording only an eagle with a prey item. Scavenging was recorded in 85% of the total occurrences and live food was taken in 15% of the cases. However, at least 118 of 137 birds (86%) recorded as prey were taken alive; i.e., hunted.

Eagles are not adverse to entering the water to obtain aquatic prey. On occasions they were seen wading in shallow water to catch or retrieve fish. Pursuing prey at times required the eagles to land on the water surface. Four hours of casual observation of feeding coastal eagles showed as many as seven immersions of these birds in water during pursuits (R. Eldridge, personal communication). Eagles were occasionally seen swimming (essentially using their wings as paddles) to shore or an ice floe clutching a fish or bird.

Carcasses of deer and offal deposits were reportedly visited regularly by wintering eagles and fed upon daily or weekly for up to two months. As many as 14 birds in aggregate were recorded at one deer kill. Eagles frequented certain coastal locales for a few days and then would change location to take advantage of a new food source (R. Eldridge, personal communication). Of the 297 eagles observed feeding in mixed age groups in New Brunswick, 44% were immatures, whereas only 12% of 277 solitary foragers were subadult birds. Mixed-age group members

were still dominated in number by adults. However, coastal concentrations of eagles seem to be dominated by immatures over adults, (R. Eldridge, personal communication).

Interactions between eagles and other birds and animals at feeding sites were fairly common. Agonistic behavior (conflicts, pursuits) was exhibited by eagles in at least 19% of 57 feeding occurrences where interactions were noted. In one instance, an adult female actively kept a smaller adult male from her gull kill; in another, two adults pursued another which had a Snowshoe Hare. Eagles chased American Crows (*Corvus brachyrhynchos*) and Common Ravens (*Corvus corax*) from road kills. Harassment and mobbing of eagles at feeding sites by crows, ravens, and gulls was common. Not all recorded interactions were aggressive; for example, crows, ravens, and gulls (in differing numbers and combinations) were the more common companions of eagles at feeding sites and their reactions to eagles varied. Occasionally they left the site when an eagle approached, or retired a short distance and returned to feed when the eagle had departed, or appeared to feed amiably with the eagle. Usually eagles would not feed at a carcass if Coyotes or Bobcats (*Lynx rufus*) were actively feeding.

The proximity of other vertebrates, including humans, or nearby human residences did not seem to deter some foraging eagles. Wintering birds were seen feeding on both cattle and deer carcasses in the midst of other herd members. An immature eagle attacked and knocked over a German shepherd dog in a field with the owner nearby. An adult bird was killed when it tried to take a snared Snowshoe Hare from the hands of a trapper carrying it. Eagles were seen going through bagged garbage at a suburban residence and frequenting a rural backyard bird feeder.

Discussion

A similar study of the diet of another northern wintering eagle population, around the lower Great Lakes basin (Ewins and Andress 1995), provides an interesting comparison with that of New Brunswick.

TABLE 3. Seasonal distribution of food items utilized by Bald Eagles in New Brunswick, 1992–1999, in percent of total observations. The three monthly groupings essentially correspond to fall, winter and spring.

Food Item	Percent Total Observations		
	October–November (n = 70)	December–February (n = 398)	March–April (n = 139)
Fish	10	3	2
Bird	49	14	9
Deer	9	49	53
Other mammals	4	5	17
Offal	28	29	19
Total	100	100	100

Aquatic animals constituted 35% of the total feeding observations at both locations. Winter-killed deer were an important food source in both studies, about 45%. Fish were utilized considerably less by New Brunswick eagles (4% vs. 23%) but offal usage was more evident (28% vs. 10%). The greater reliance on offal by immature eagles was evident in both studies. An analysis of prey remains in eagle pellets in the Lower Great Lakes basin (Lang et al. 1999) suggested similar results using a non-observational method.

The aquaculture industry, specifically the cage-rearing of Atlantic Salmon in salt water along the Bay of Fundy, appeared to have contributed considerably to the prey base of wintering eagles here. Culled salmon have been put out for eagles by a number of operators in recent years. This almost certainly influenced wintering eagle distribution and abundance. A highly significant correlation exists between the number of aquaculture sites along the coast and number of eagles seen there on Christmas Bird Counts, 1979 to 1997 (Stocek, unpublished). However, when coastal wintering eagles are ready to disperse to inland locales in early spring the availability of salmon offal seems relatively unimportant to them (R. Eldridge, personal communication).

Bald eagles are not especially efficient hunters of healthy water birds. Only three of 29 (10%) hunting attacks observed on diving birds (cormorants, guillemots and eiders) in New Brunswick were successful. Other studies suggest comparable hunting inefficiency, e.g., 20% in Maine (Todd et al. 1982), 12% in Alberta (Dekker 1984), and five of "many" attempts in Missouri (Griffin et al. 1982). Although waterfowl represented only a small percentage (4%) of the total feeding occurrences, they are especially important in terms of biomass and energy to foraging eagles during the winter (Stalmaster and Plettner 1992). The higher incidence of both seabirds and waterfowl in the coastal eagle diet during the winter is also seen in nearby Maine (Todd et al. 1982).

Using the direct approach of observing feeding eagles is not without some associated biases. It usually is easier to see a bird feeding in an exposed open area such as a field or on ice than one perched along the shoreline. Eagles with large prey are more likely to be noticed than those with smaller items such as fish. Adults are easier to see than the less contrasted immatures. Perhaps the accurate assessment of Bald Eagle diet requires a combination of different techniques (Mersmann et al. 1992).

Bald Eagles acquire food by three means: (1) stealing prey from others — pirating (from other eagles) or kleptoparasitism (from other species), (2) scavenging on carrion and (3) hunting and killing (Stalmaster 1987). New Brunswick eagles apparently rely heavily on scavenging. Although many birds are taken alive during hunting, this foraging method

accounts for less than 20% of the total feeding observations. Stealing food from others was seemingly not as common as reported elsewhere (Todd et al. 1982; Dekker 1984), but this method of acquiring food is surely used more than 1% of the time. In contrast, Stalmaster and Plettner (1992), recording 1395 winter foraging attempts in Nebraska, noted 87% involved hunting, 9% piracy, and 40% scavenging.

Young eagles rely more than adults on scavenging and stealing to get their food (Stalmaster 1987; Sabine and Klimstra 1985; Fischer 1985), probably because they are less adept or effective at capturing live prey (Stalmaster and Plettner 1992; Sherrod et al. 1976) or are supplanted by adult birds at mixed feeding groups (Erskine 1968). They commonly use the presence of other eagles as indicators of food during the winter and follow them to feeding grounds (Knight and Knight 1983). The preponderance of immatures in mixed feeding groups relative to solitary foragers in New Brunswick suggests that they may be less efficient at foraging than adults (Stalmaster and Gessaman 1984; Craig et al. 1988) and are more usually seen feeding with them (Fischer 1985).

The reliance on more terrestrial dietary items, such as mammals and offal, by inland wintering eagles suggests they are exposed to a reduced risk of environmental contaminants there. Coastal birds feed more heavily on aquatic organisms and it is here that contaminant problems could arise for this high-level predator. To what extent New Brunswick eagle reproductive potential is compromised, if at all, has yet to be determined.

This versatile opportunistic raptor uses foraging strategies that are best suited to the habitat and the availability of prey in the winter environment. Consequently the variety of dietary items consumed is different among various wintering areas. For example, mammals may be a more important food source in some areas (e.g., Ewin and Andress 1995; Todd et al. 1982), waterfowl in others (e.g., Griffin et al. 1982; Grubb and Kennedy 1982) and fish elsewhere (e.g., Stalmaster and Plattner 1992). Yet these preferences can change or shift as other prey items become available. The Bald Eagle is truly a bird of flexible and adaptive feeding habits.

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Appendix 1.

List of food items utilized by wintering Bald Eagles in New Brunswick, 1992–1999.

Fish

American Eel (*Anguilla rostrata*)
Atlantic Salmon (*Salmo salar*)
Rainbow Smelt (*Osmerus mordax*)
Atlantic Tomcod (*Microgadus tomcod*)
Hake (*Urophycis* spp.)
Flounder (Bothidae)
unidentified fish

Birds

Common Loon (*Gavia immer*)
Double-crested Cormorant (*Phalacrocorax auritus*)
Canada Goose (*Branta canadensis*)
Black Duck (*Anas rubripes*)
Mallard (*Anas platyrhynchos*)
Domestic Duck (*Anas platyrhynchos*)
Greater Scaup (*Aythya marila*)
Common Eider (*Somateria mollissima*)
Common Goldeneye (*Bucephala clangula*)
American Merganser (*Mergus merganser*)
unidentified duck
Ring-necked Pheasant (*Phasianus colchicus*)
Ruffed Grouse (*Bonasa umbellus*)
Wild Turkey (stocked) (*Meleagris gallopavo*)
Herring Gull (*Larus argentatus*)
Great Black-Backed Gull (*Larus marinus*)
unidentified gull
Black Guillemot (*Cepphus grylle*)
Razor-billed Auk (*Alca torda*)
Rock Dove (*Columba livia*)
Great Horned Owl (*Bubo virginianus*)

Mammals

Snowshoe Hare (*Lepus americanus*)
Domestic Rabbit (*Oryctolagus cuniculus*)
Grey Squirrel (*Sciurus carolinensis*)
Beaver (*Castor canadensis*)
Muskrat (*Ondatra zibethicus*)
Meadow Vole (*Microtus pennsylvanicus*)
Harbour Porpoise (*Phocoena phocoena*)
Minke Whale (*Balaenoptera acutorostrata*)

Eastern Coyote (<i>Canis latrans</i>)	Invertebrates
Domestic Dog (<i>Canis familiaris</i>)	Marine Annelid (Polychaeta)
Raccoon (<i>Procyon lotor</i>)	
Domestic Cat (<i>Felis catus</i>)	Offal
Harbour Seal (<i>Phoca vitulina</i>)	Fish remains (aquaculture)
White-tailed Deer (<i>Odocoileus virginianus</i>)	Poultry remains
Moose (<i>Alces alces</i>)	Cattle remains
Cow (<i>Bos taurus</i>)	Swine remains
Domestic Sheep (<i>Ovis aries</i>)	Dog kennel food remains
unidentified mammal	

Dune Colonization in the Bald Head Hills, Southwestern Manitoba

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In order to document the micro-environment, vegetation, and successional patterns in the Bald Head Hills in southwestern Manitoba, one of the few extensive sand prairie habitats in Canada, we studied four sites representing different successional stages. Sites were selected based on varying proportions of bare sand and vegetation cover. At each site we collected soil samples, recorded soil and air temperatures, soil moisture, rainfall, and sand movement. We also sampled vegetation cover and plant rooting depths. All sites were xeric, with medium texture, nutrient poor, sandy soil with good to excessive drainage. Soil organic content, moisture, and nutrient retention increased from the earliest to the latest stage of colonization. Soil moisture of the latest stage was depleted during the growing season, while that at deeper levels (40–60 cm) of the early stages were not. Local sand accretion and erosion rates differed from year to year. Overall short-term sand movement was 0.2 m yr⁻¹, less than that reported for other dune systems. Long-term sand movement in the leading edge of the dune system, determined from 1948, 1974, and 1994 aerial photographs, was negligible, but vegetation cover increased from 14 to 66%. In our samples mean plant cover increased from < 3% in Site I to 73% in Site IV while the number of species increased from 11 to 75. Many of these species displayed typical adaptations to drought, including leaf modifications, photosynthetic pathways, and root types. *Andropogon gerardi*, *Oryzopsis hymenoides*, *Petalostemum candidum*, and *Koeleria cristata* characterized early successional stages, and *Bouteloua gracilis*, *Stipa spartea*, *Cladonia* spp., and *Selaginella densa*, later stages. Changes in species composition were highly correlated with soil organic content. The stresses imposed by mobile sand are important factors in limiting plant establishment on the open sand, while drought and temperature extremes limit plant growth on partially and fully stabilized dunes.

Key Words: sand dune colonization, sand prairie, *Andropogon gerardi*, Big Bluestem, *Bouteloua gracilis*, Blue Grama, *Selaginella densa*, Prairie Selaginella, organic content, soil moisture, Bald Head Hills, Carberry Sand Hills, Manitoba.

Sand dunes are xeric environments with high diurnal soil and air temperature variation, low soil moisture retention, low cation exchange capacity, and low fertility (Willis and Yemm 1961; Chandapillai 1970; Barnes and Harrison 1982; Baldwin and Maun 1983; Maun 1985). In addition, moving sand abrades and buries colonizing plants, and can even obliterate well-established communities. Unlike coastal dunes, inland dunes are not enriched by allogenic processes such as the accumulation of water-borne litter, and because of the paucity of vegetation, autogenic processes are slow and easily reversed by moving sand (Olson 1958). Where there is sand movement, vegetation colonization occurs slowly and sporadically. Previous studies of the micro-environments and the vegetation of sand dunes at different stages of colonization cover a wide geographical range including sites in Saskatchewan (Hulett et al. 1966), North Dakota (Burgess 1965), on Lake Michigan (Cowles 1899; Olson 1958; Weller 1989), in Idaho (Chadwick and Dalke 1965), Oregon (Kumler 1969), California (McBride and Stone 1976), England (Ranwell 1958, 1959), the Netherlands (Olff et al. 1993), Israel (Kutiel et al. 1980), and Namibia (Yeaton 1988).

Successional studies show that early stages of sand dune colonization are subject to considerable sand movement where vegetation is sparse. Later stages have soils with greater water and nutrient holding capacity, and support plant communities with greater cover, density, and diversity (Hulett et al. 1966; Morrison and Yarranton 1973, 1974; Barnes and Harrison 1982; Baldwin and Maun 1983; Yeaton 1988).

The Bald Head Hills in southwestern Manitoba support sand prairie plant communities in various stages of dune colonization. The instability and low productivity of sand prairie soil has generally protected even the vegetated portions of the area from agriculture. Thus, they are among the last extensive and minimally impacted habitats for native prairie flora.

The objective of this study was to describe the vegetation and micro-environment of four sand dune communities at different stages of colonization. An assessment of dune colonization from aerial photographs between 1948 and 1994 was also involved.

Study Area

The Bald Head Hills (49°40'N, 99°17'W), also known as the Carberry Sand Hills, cover 427 ha. but

are part of an extensive complex of sand dunes located in southwestern Manitoba. The Bald Head Hills are one of the best examples of sand dunes in Canada (Parks and Natural Resources Branch 1998*). They straddle the boundary between the Shilo Military Reserve to the west and Spruce Woods Provincial Park to the east (Figure 1). Within the park, they are in the protected land use category (Manitoba Parks Branch 1987*). A number of plant taxa occurring in the Bald Head Hills are not only rare in Manitoba (White and Johnson 1980), but also rare in Canada. These include *Andropogon hallii* (Sand Bluestem), *Aristida longiseta* (Red Three-awn), *Asclepias lanuginosa* (Hairy Milkweed), *Polanisia dodecandra* ssp. *dodecandra* (Clammyweed), *Oryzopsis hymenoides* (Indian Rice Grass), and *Townsendia exscapa* (Low Townsendia). Despite their unique flora and fauna, studies have been limited to a plant phenology and species list (Criddle 1927), brief descriptions of topography, climate, and plant communities (Bird 1927), dune movement (Bird 1961), a popular article (Nero 1976*), and a discussion of management strategies for sandhill communities in southwestern Manitoba (Marr Consulting and Communications Ltd. 1995*).

The Bald Head Hills were formed from the surface sands of the Upper Assiniboine Delta which cover approximately 135×70 km, and are up to 80 m deep (Davies et al. 1962*). The delta is part of an outwash plain that lies above the Manitoba Escarpment (Ehrlich et al. 1957) where the ancient Assiniboine River flowed into glacial Lake Agassiz. These outwash sands have been formed by wind into dunes which are now mostly stabilized. The dominant soil landscape of the delta is aeolian sand with a hummocky surface form (slope 4–9 %) (Canada Soil Inventory 1989). Soils are regosolic and the drainage is good to excessive. Water-table depth is greater than 3 m. Windward slopes are gentle while lee slopes are steep and at the angle of repose. Behind the active dunes there are rolling hills stabilized by mixed-grass prairie with thin black soils of the Chernozemic order (Ehrlich et al. 1957), dominated by *Andropogon gerardii*, *Koeleria cristata*, and *Oryzopsis hymenoides* with scattered *Picea glauca* and groves of *Populus tremuloides* (Bird 1961) [See Appendix for common names].

The vegetation of the study area has been classified in several ways. It is located between the mixed wood and aspen-oak sections of the Boreal Forest Region (Rowe 1972), it falls into the Upper Assini-

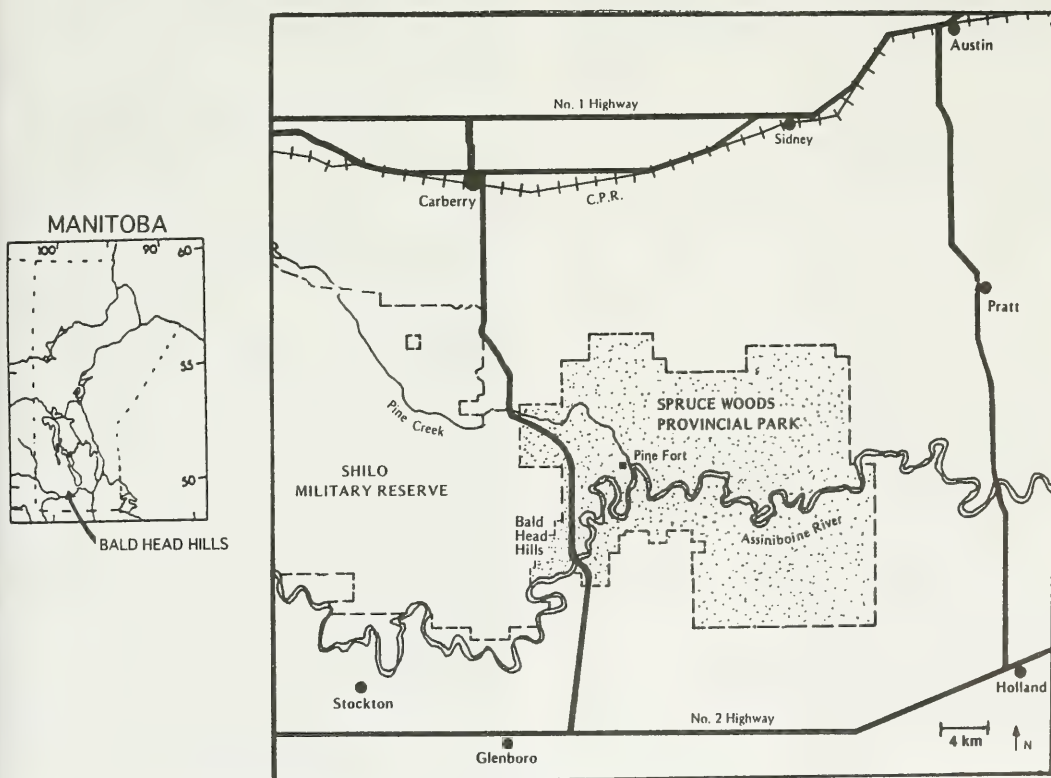


FIGURE 1. Location of the Bald Head Hills in south-western Manitoba.

boine Delta Ecoregion of the Ecological Land Classification (Poston et al. 1990), and the Aspen Parkland Terrestrial Ecoregion (Ecological Stratification Working Group 1995*).

The local climate is humid continental with long cold winters and short warm summers (Ecological Stratification Working Group 1995*). The mean daily maximum temperature between 1951 and 1980, recorded at Shilo 28 km to the northwest (49°48'N, 99°9'W) was 26.4°C in July, and -14.2°C in January. Annual precipitation was 499.3 mm, with 73% (363.5 mm) falling from May through October. Annual snowfall (water equivalent) was 129.2 mm and the mean annual moisture deficit was 14.2 cm yr⁻¹ (Atmospheric Environment Service 1982). More recent climate normals for Shilo are not recorded (Atmospheric Environment Service 1993).

Methods

Using aerial photographs and ground reconnaissance, four sites within 0.6 km of one another (Figure 2b) were chosen to represent different stages of colonization according to sand mobility and vegetation cover. These ranged from bare, mobile sand through progressively stabilized and colonized sites to mixed sand prairie.

Field sampling

Environmental variables and vegetation cover in these sites were sampled each month from May to October (five sampling dates) in 1976 and 1977. The May and September data for both years are presented here. Four soil pits were dug at each site to provide data on soil profiles and plant rooting depths. As there were no obvious soil horizons, soil samples were taken at 0–5 cm and 40–60 cm, the lower limit of the major rooting zone. Samples were placed in polythene bags and sealed for later analysis.

Soil moisture profiles were recorded from 4 June to 2 October at all sites. A Bouyoucous meter (BN-2B) and CEL-WFD gypsum blocks recorded soil moisture as a percentage of field capacity at 5, 10, 20, and 30 cm below the surface.

From early May until October, air and soil temperatures were recorded at hourly intervals at Sites I and IV. Probes of a Grant recorder were positioned at +50, 0 cm above, and -5, -0, -20, and -30 cm below the surface. Accumulated rainfall was measured bi-weekly for two years using a wedge-type rain gauge placed 15 cm above the ground. A surface film of mineral oil prevented evaporation from the gauge.

Short-term sand movement was measured at Site I. Four 2 m stakes were placed 50 m apart across a dune, parallel with the prevailing wind, and fifteen 2 m stakes were placed 3 m apart in the dune trough, perpendicular to the prevailing wind. Changes in sand depth relative to the stakes were recorded at two-week intervals from June to October in the first year of the study and May to October in the second year.

The vegetation was sampled at four-week intervals from May through September. The percent cover of bare ground and vegetation was estimated, using a modified Braun-Blanquet scale (1932), in 25 randomly placed 25 × 25 cm quadrats in each site. The mean cover of species and bare ground was calculated using the midpoints of the Braun-Blanquet classes. Nomenclature of vascular plants follows Scoggan (1978–1979), except for *Andropogon scoparius* Michx. where the current, more acceptable synonym *Schizachyrium scoparium* ssp. *scoparium* (Michx.) Nash is used (Kartesz 1994). Lichens were identified to genus using Hale (1969) and mosses using Crum (1976). Voucher specimens were deposited in the University of Manitoba Herbarium (WIN).

Lab analysis

Soil samples were air-dried. Their color was determined using Munsell color charts (Anonymous 1969). Sub-samples were sieved into coarse (2.0–0.5 mm), medium (0.5–0.25 mm), fine (0.25–0.125 mm), and very fine (0.125–0.053 mm) fractions (Brady 1974). The rate of settling from suspension was used to estimate silt and clay (Kilmer and Alexander 1949). Field moisture capacity was determined using air-dried subsamples (Brady 1974). Conductivity and pH were measured from a slurry of 75 ml distilled water and 100 g dry soil. Conductivity was measured using a Radiometer Copenhagen conductivity meter type CDM 2e and a CDC 104 electrode, and for pH a Radiometer #29 pH meter was used. Organic content was determined by loss on ignition (350°C, 2 hr). Available nitrate, phosphate, and potassium were analyzed by the Manitoba Provincial Soil Testing Laboratory using standard techniques (McKeague 1978).

Vegetation cover in the leading edge (enclosed by the dashed line in Figures 2a and 2b) of the dune system was calculated using black-and-white aerial photographs from 5 August 1948 (1:15 900), n.d. July 1974 (1:15 900), and 7 September 1994 (1:31 680), and the NIH Image v. 1.59 program.

Statistical analysis

Differences in soil data among sites were analysed using ANOVA and Scheffe's test for inequality of means (Sokal and Rohlf 1969). Canonical Correspondence Analysis (CCA) was selected in order to correlate differences in species composition with environmental variables, and was performed on species with a mean cover of 1% or greater in at least one site and bare ground, using CANOCO version 3.10 (ter Braak 1990). These data were square-root transformed prior to analysis. Soil organic content, conductivity, and available nitrate were used as environmental variables in the analysis.

Results

Micro-environment

Soils at all sites were predominantly composed of

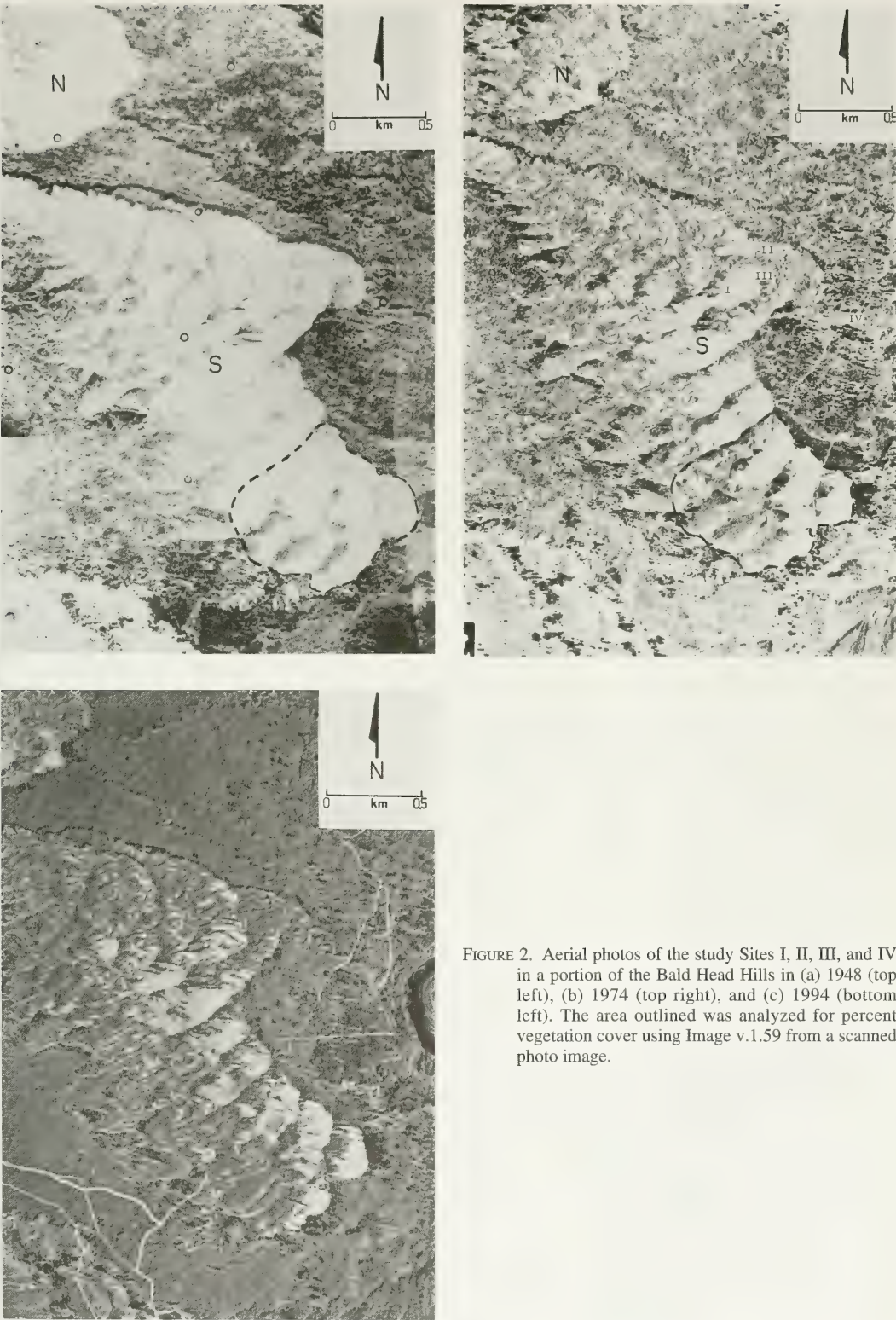


FIGURE 2. Aerial photos of the study Sites I, II, III, and IV in a portion of the Bald Head Hills in (a) 1948 (top left), (b) 1974 (top right), and (c) 1994 (bottom left). The area outlined was analyzed for percent vegetation cover using Image v.1.59 from a scanned photo image.

medium and fine sand (Table 1), but were progressively finer in texture from Site I to Site IV. Soil pH ranged from 7.6 to 8.3, and organic content, conductivity, available nitrogen, phosphorous, and potassium were low (Table 1). Site IV, with the greatest cover of vegetation, had significantly ($P < 0.05$) higher organic and nitrate content than Sites I to III. The Munsell colour of dried soil with lower organic content ranged from light olive brown (2.5 Y 5/4, Anonymous 1969) in Sites I and II to dark yellowish brown (10 YR 4/4) in Site III, and was dark greyish brown (10 YR 4/2) for soils with higher organic content in Site IV.

Soil and air temperatures were generally higher at Site I than Site IV (Figure 3). Although soils at Site IV were shaded by plant cover their darker colour absorbed more heat than the reflective light-coloured sands of Site I. Thus, the surface soils of both sites were relatively warm, but the air above Site IV was cooler than that above Site I due to the influence of denser vegetation which was transpiring. Throughout the growing season, the soil temperature regimes of Sites I and IV exhibited wide diurnal fluctuations which decreased in magnitude with soil depth (Figure 3). During the day, soil temperatures decreased with depth but the gradient reversed at night.

The mean precipitation for all sites from June through September the first year was 210 mm but it varied between sites. Sites I, II, and III each received

207 mm and Site IV received 220 mm. Mean precipitation for June through September the second year was 332 mm. Soil moisture content was significantly correlated with rainfall ($R^2 = 0.56$, $P < 0.05$).

Mean soil moisture (as a percentage of field capacity) was significantly greater at all depths in Site I than in other sites. It was lowest in Site IV, except at 5 cm, and similar at all depths in Sites II and III. Sites I to III showed a gradient of increasing soil moisture from surface to subsoil, but this did not differ with depth in Site IV. All sites showed a trend of decreasing soil moisture over the growing season. Moisture retention of the soils increased with the increase in organic content from Sites I to IV. At field capacity, soils in Sites I-III contained 18–19% water by weight, while those in Site IV contained 30%.

Sand movement is characteristic of pioneer stages of dune colonization. At Site I, the wind eroded sand from the heel and mid-crest of the dune with subsequent accretion at the crest and toe (Figure 4a). The maximum accumulation of sand at one stake was 28 cm and maximum sand loss at another was 35 cm. Leeward edges moved 15–20 cm yr^{-1} . Sand also eroded from the trough between two dunes (Figure 4b) with less accretion on the more vegetated side.

Aerial photographs did not show appreciable overall dune movement between 1948 and 1994. Vegetation cover in a leading edge section of the

TABLE 1. Mean soil properties \pm standard deviation for Sites I to IV in the Bald Head Hills.

Property	Depth (cm)	Site I Bare dune	Site II Intermediate	Site III	Site IV Sand prairie
pH	0–5	8.3 \pm 0.1	7.9 \pm 0.2	7.7 \pm 0.2	7.6 \pm 0.2
	40–60	8.3 \pm 0.1	8.3 \pm 0.1	8.2 \pm 0.2	8.0 \pm 0.3
Organic matter (%)	0–5	0.2 \pm 0.2	0.6 \pm 0.4	1.2 \pm 0.4	3.5 \pm 1.4*
	40–60	0.2 \pm 0.1	0.3 \pm 0.1	0.4 \pm 0.3	0.7 \pm 0.3
Conductivity (μmhos)	0–5	106 \pm 10	164 \pm 38	241 \pm 86	548 \pm 238
	40–60	118 \pm 9	113 \pm 9	34 \pm 30	171 \pm 12
Nitrate (ppm)	0–5	0.3 \pm 0.2	1.1 \pm 1.1	1.5 \pm 0.6	4.9 \pm 2.4*
	40–60	0.3 \pm 0.1	0.4 \pm 0	0.7 \pm 0.6	0.9 \pm 0.9
Available P (ppm)	0–5	1.2 \pm 0.1	1.8 \pm 0.7	3.7 \pm 1.9*	1.4 \pm 0.8
	40–60	1.6 \pm 0.8	0.9 \pm 0.1	1.3 \pm 0.6	0.9 \pm 0.2
Available K (ppm)	0–5	28 \pm 5	30 \pm 4	57 \pm 21	95 \pm 18
	40–60	27 \pm 2	20 \pm 2	26 \pm 6	29 \pm 9
Particle sizes ¹					
Coarse sand (2.0–0.5 mm)	0–5	9 \pm 7	3 \pm 2	4 \pm 2	2 \pm 1
	40–60	5 \pm 4	7 \pm 3	4 \pm 2	2 \pm 8
Medium sand (0.5–0.25 mm)	0–5	70 \pm 7	61 \pm 6	48 \pm 10	26 \pm 2
	40–60	64 \pm 5	65 \pm 3	65 \pm 17	59 \pm 11
Fine sand (0.105 mm)	0–5	20 \pm 6	40 \pm 4	40 \pm 7	53 \pm 6
	40–60	30 \pm 8	27 \pm 4	30 \pm 16	37 \pm 10
Very fine sand (0.125–0.053 mm)	0–5	1 \pm 1	1 \pm 1	7 \pm 4	14 \pm 3
	40–60	1 \pm 1	1 \pm 0	2 \pm 3	1 \pm 1
Silt and clay (<0.053 mm)	0–5	0	0	1 \pm 1	5 \pm 2
	40–60	0	0	0	0

¹Percent weight.

*Significantly differed ($P \leq 0.05$) from other sites.

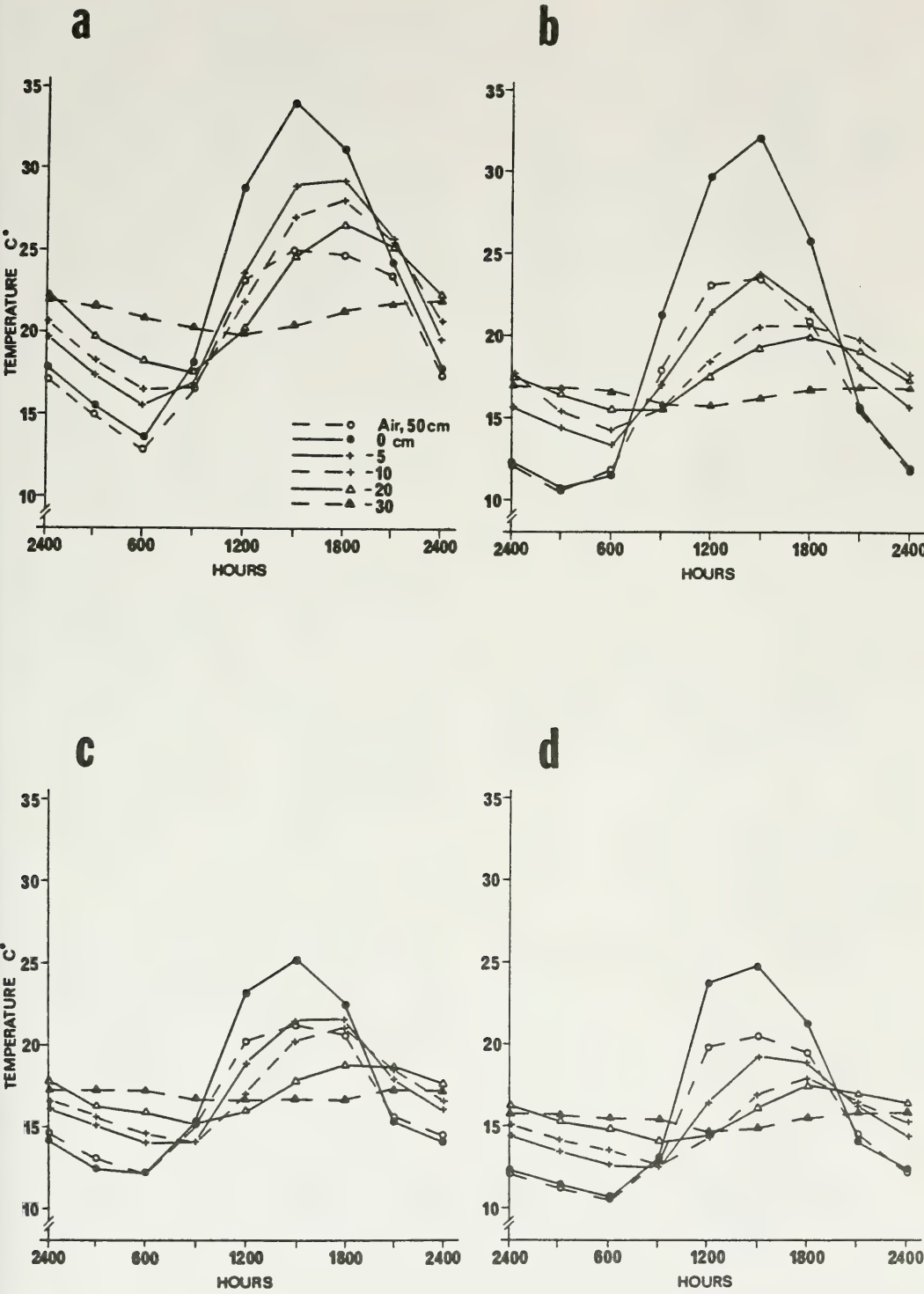


FIGURE 3. Mean daily air and soil temperatures at various depths in Site I and IV over a two week period at two different stages of the growing season; (a) Site I and (b) Site IV commencing 24 June, (c) Site I and (d) Site IV commencing 2 September.

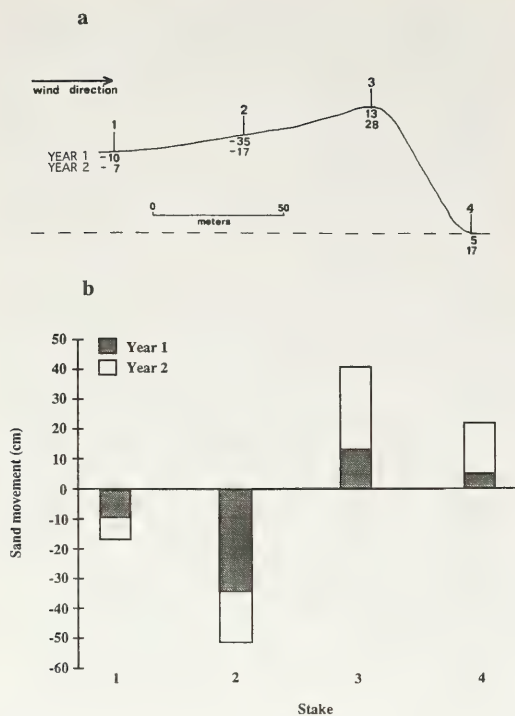


FIGURE 4. Sand movement on an open sand dune between May and October in each of two subsequent years; (a) sand levels were measured against stakes placed every 50 m on the dune, (b) sand erosion is indicated by negative values and deposition by positive values.

dunes, an area of approximately 0.6 km², enclosed by the dashed line in Figures 2a and 2b, increased from about 14% in 1948 to 43% in 1974, to 66% in 1994.

Vegetation composition

There were 22 families, 75 genera, and 98 species of vascular plants represented in the four sites. Two-thirds of the species were members of five families; Compositae (26.3%), Gramineae (Poaceae) (21.0%), Rosaceae (9.2%), Leguminosae (6.6%), and Cyperaceae (4.0%).

The amelioration of xeric conditions was reflected in the increasing plant cover and number of species from Sites I to IV (see Appendix). The number of species in the samples changed from 11 in Site I, to 23 in Site II, 35 in Site III, and 75 in Site IV. The mean seasonal cover (May and September for both years) of vegetation increased from <3% in Site I to 73% in Site IV. Bare ground decreased in a corresponding manner.

The highest mean cover of any species was less than 10% with marked changes in the mean cover of key species from Site I to Site IV (Table 2). For example, the mean cover of *Andropogon gerardi*

was low in Site I, reached a maximum of 8% in Site II, and gradually decreased in Sites III and IV. *Koeleria cristata* and *Petalostemum candidum* also followed this trend reaching maximum cover in Site II. Other species were characteristic of Sites III or IV. *Schizachyrium scoparium* was absent from Site I, its cover increased from 1% in Site II to 9% in Site III, and decreased to 3% in Site IV. *Juniperus horizontalis*, *Bouteloua gracilis*, and *Stipa spartea* were only present in Sites III and IV but all three peaked in Site IV (Table 2). Mosses and lichens were confined to Sites III and IV (Table 2). Some species, e.g., *Helianthus petiolaris*, had a high frequency in Site II, but mean cover less than 1% (Ward 1980).

The cover and composition of vegetation in each site varied throughout the season. Maximum vegetation cover was recorded in July and August in Site I, and in August in Sites II to IV (Figure 5). The number of species per quadrat, as a measure of species richness, also followed this trend. Species richness in Sites II and III did not significantly differ but that of Site I was lower and Site IV higher ($P < 0.05$) (Appendix).

The CCA ordination showed separation of plot scores among sites (Figure 6). Early stages of colonization, found on the left side of the ordination, were characterized by *Petalostemum candidum*, *Koeleria cristata*, *Andropogon gerardi*, and bare ground. Site IV plots, on the right side of the ordination, were characterized by *Bouteloua gracilis*, *Selaginella densa*, *Cladonia* spp., and *Stipa spartea*.

The soil variables used in the analysis (organic content, conductivity, and nitrate) were highly correlated with species composition ($R^2 = 0.96$), and increased from Site I to Site IV (Figure 6). Eigenvalues indicated that axis 1 accounted for 42% of the variation in the data set. The canonical coefficient for soil organic content was 0.77, 0.25 for nitrate, and 0.06 for conductivity.

Discussion

Micro-environment

Soil characteristics of the Bald Head Hills are similar to those of other sand prairie and dune sites (Chadwick and Dalke 1965; Baldwin and Maun 1983; Maun 1985). The pH was slightly basic, and had low cation exchange capacity and nutrient status. Sand composed $\geq 95\%$ of the soil particles by weight, with an increasing proportion of fine sand on more stabilized and densely colonized sites. Chadwick and Dalke (1965) also found a high percentage of sand in stabilized sand prairie sites in Idaho, where fine sand composed $> 95\%$ of the soil particles. In the Great Sand Hills of Saskatchewan, there was a 93% sand fraction in the active dune complex, but only 87 and 71% sand fraction on stabilized sand dunes and flats (Hulett et al. 1966). Our results showed increasing organic matter of 0.2% in sparse to 3.5% in densely colonized sites. This is

similar to the 0.1% organic matter in sparsely colonized sites, and 3 to 5% in well-vegetated sites on Lake Huron sand dunes (Baldwin and Maun 1983).

In the absence of plant cover, sand warms and cools more rapidly and to greater extremes than loam or clay-rich soils (Pool 1916; Steiger 1930; Ayyad and Dix 1964). At Site I with < 3% plant cover, surface soil temperatures were higher than the ambient air temperature, but at Site IV, with > 73% plant cover, they were lower. Baldwin and Maun (1983) also observed this trend.

Surface soil moisture as a percentage of field capacity was high in spring and summer, and decreased from mid-August until October. Soil moisture depletion was most rapid in the densely colonized Site IV where the top 30 cm was completely dry by the beginning of September. In Site I, soil moisture was 100% of field capacity at depths of 20 and 30 cm throughout the growing season and the top 5 cm did not become dry until October. This trend was also seen in sand prairie sites in the Nebraska sand hills (Barnes and Harrison 1982) and in Lake Huron sand dunes (Baldwin and Maun 1983).

At field capacity, the soils at Sites I to III held approximately 10% less moisture by weight than Site IV. Site IV had more moisture available to support vegetation than the other sites. Barnes and Harrison (1982) and Baldwin and Maun (1983) also found that fine-textured soils with more plant cover had a higher soil moisture content. Moisture is lost through evaporation and plant transpiration, but the dry surface layer acts as a mulch to reduce drying of deeper layers (Pool 1916). At night, water vapour from the moist subsoil is drawn upward as the surface sands cool (Pool 1916; Ranwell 1972). When temperatures fall below the dew point, atmospheric humidity condenses on the sand grains, adding moisture to the soil (Salisbury 1952; Ranwell 1972). The finer-textured soils at Site IV presumably lost less water through surface evaporation, but their decreased porosity and higher specific heat would lead to less dew formation. Denser plant cover at Site IV removes soil moisture from the rooting zone via evapotranspiration (Ranwell 1959). Increased soil organic matter may decrease soil wettability and hence moisture penetration (Jamison 1956; Coupland 1961). In Saskatchewan (Ayyad and Dix 1964), plant cover was a significant factor in differences in vapour pressure between colonized and bare areas.

The rate of dune movement calculated in this study (0.2 m yr^{-1}) is considerably slower than those reported for other dune systems. The portion of the dunes we compared on aerial photographs for overall change in plant cover, showed that 14% of the dunes was vegetated in 1948 and 66% by 1994. The development of plant cover followed the prevailing winds from the northwest to the southeast. The leading edges in the southeast depend upon incoming sand to

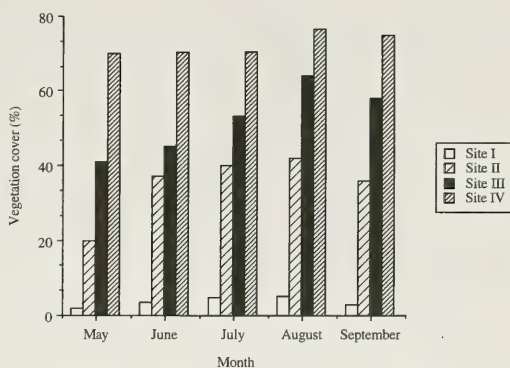


FIGURE 5. Total vegetation cover (%) in Sites I, II, III, and IV over the growing season, averaged for years 1 and 2 of the study.

retard the speed of colonization. By 1994, there was little open sand in the northwest to feed the leading edges of the overall dune system. Movement of dunes is presumably restricted because there is no new sand deposition, leaving only blowout pockets of sand to feed the advancing edge (Chadwick and Dalke 1965). If these conditions continue, within a decade or two most of the Bald Head Hills will be vegetated.

Sand movement was up to 0.3 m yr^{-1} in Namib dune grasslands (Yeaton 1988), 0.1 to 4 m yr^{-1} in Lake Michigan dunes (Cowles 1899; Gates 1950; Weller 1989), 3 m yr^{-1} in Idaho dunes (Chadwick and Dalke 1965), 0.6 to 6.6 m yr^{-1} in Saskatchewan (Hulett et al. 1966), and up to 24 m yr^{-1} on British coastal dunes (Ranwell 1958).

Vegetation

There was a striking increase in the number of species from Site I to Site IV. We recorded 11 species in Site I, the active dunes. Hulett et al. (1966) reported 14 taxa in active dunes in the Great Sand Hills of Saskatchewan. Six of the same species occurred in our Site I, where our *Corispermum simplicissimum* was replaced by *C. orientale*. In our sampling in Site IV, we recorded 75 vascular taxa (Appendix). Of these, 40% occurred frequently in the stabilized dunes of Hulett et al. 1966). The species composition and family proportions were also similar to those of the Wisconsin sand prairies (Curtis 1959).

Morrison and Yarranton (1973) studied sand dunes from 100 to 4800 years old at Grand Bend in Ontario. They reported an initial increase in species richness, followed by a leveling off at around 1000 years. Thereafter the rate of increase progressively declined. Our sites were undated but we know that the cover of vegetation on the leading edge of one dune system changed from 14% in 1948 to 66% by 1994, 46 years later (Figures 2a, b and c). The importance of sand movement is further highlighted

TABLE 2. The mean cover (%) of species >1.0 % in at least one site. Sampled from May through September in years 1 and 2 of the study. Common names are in the Appendix.

Taxa	Site			
	I (n=250)	II (n=250)	III (n=250)	IV (n=250)
Bare ground	97.6	64.4	47.7	26.6
Shrubs				
<i>Arctostaphylos uva-ursi</i>	—	—	—	1.1
<i>Elaeagnus commutata</i>	0.1	1.2	0.8	—
<i>Juniperus horizontalis</i>	—	—	8.8	9.6
<i>Prunus pumila</i>	—	—	—	1.1
<i>Rosa blanda</i>	—	—	0.3	1.4
Grass-like				
<i>Andropogon gerardi</i>	0.2	8.3	5.8	1.1
<i>Bouteloua curtipendula</i>	—	0.6	0.9	1.7
<i>Bouteloua gracilis</i>	—	—	0.1	8
<i>Calamovilfa longifolia</i>	—	0.1	3.5	0.7
<i>Carex</i> spp.	—	0.1	0.8	6.5
<i>Festuca ovina</i>	—	0.1	1.6	0.3
Gramineae spp.	—	0.1	0.1	1.1
<i>Koeleria cristata</i>	—	9.3	7.5	0.2
<i>Oryzopsis hymenoides</i>	1.1	0.1	—	0.4
<i>Schizachrium scoparium</i>	—	0.8	8.9	3.1
<i>Stipa spartea</i>	—	—	—	6.2
Herbs				
<i>Artemisia biennis</i>	—	3.5	1.5	0.7
<i>Artemisia frigida</i>	—	—	0.1	1.7
<i>Helianthus laetiflorus</i>	—	—	—	2
<i>Lithospermum canescens</i>	—	—	—	1.6
<i>Lithospermum incisum</i>	—	—	—	1.3
<i>Petalostemum candidum</i>	0.2	6.6	0.4	—
<i>Petalostemum purpureum</i>	—	—	0.2	1
<i>Selaginella densa</i>	—	—	—	3.2
<i>Solidago nemoralis</i>	—	2.1	4.3	0.2
Mosses and Lichens				
<i>Bryum</i> spp.	—	—	1.1	0.8
<i>Cladonia pyxidata</i>	—	—	0.2	1.9
<i>Cladonia</i> spp.	—	—	0.1	3.5
<i>Tortula ruralis</i>	—	0.4	1.2	—

by Yeaton (1988) who found an inverse correlation between vegetation density and rate of sand movement in Namib dune grasslands.

The Bald Head Hills flora exhibits many xerophytic adaptations. Several species display modifications of photosynthetic organs intended to reduce water loss, e.g., narrow rolled leaves (*Stipa spartea*), sclerophylls (*Juniperus* spp.), reflective epidermis (*Andropogon gerardi*, *Elaeagnus commutata*), hairs (*Oxytropis lambertii*), or replacement of leaves with photosynthetic stems (*Lygodesmia juncea*).

Plants that need less moisture have a competitive advantage over less efficient plants when stressed by low moisture. Those designated as C_4 plants need about half the water required by C_3 plants to produce a unit of dry matter (Waller and Lewis 1979). This is because plants with the C_4 photosynthetic pathway differ from C_3 plants in a number of ways. Carbon

dioxide fixation initially yields 4-C acids (hence the C_4) compared with the C_3 photosynthetic pathway where 3-C acids are produced. The C_4 net photosynthetic rate is two to three times greater, CO_2 compensation points are lower and CO_2 is not evolved during illumination. The optimum temperature for CO_2 uptake by C_4 plants is 30 to 40°C with uptake decreasing rapidly below 15 to 20°C. The optimum temperature for C_3 plants ranges from 10 to 25°C with a sharp decrease above 25°C (Waller and Lewis 1979). The C_4 photosynthetic pathway is more efficient than the C_3 system under conditions of high light, high temperature and water stress that characterizes sand prairies in mid-summer (Ode et al. 1980). Of the 15 grasses recorded in our study, eight are C_3 as are the sedges. Barnes et al. (1983) studied a South Dakota prairie and showed that C_4 biomass was greatest on soils with low to moderate moisture,

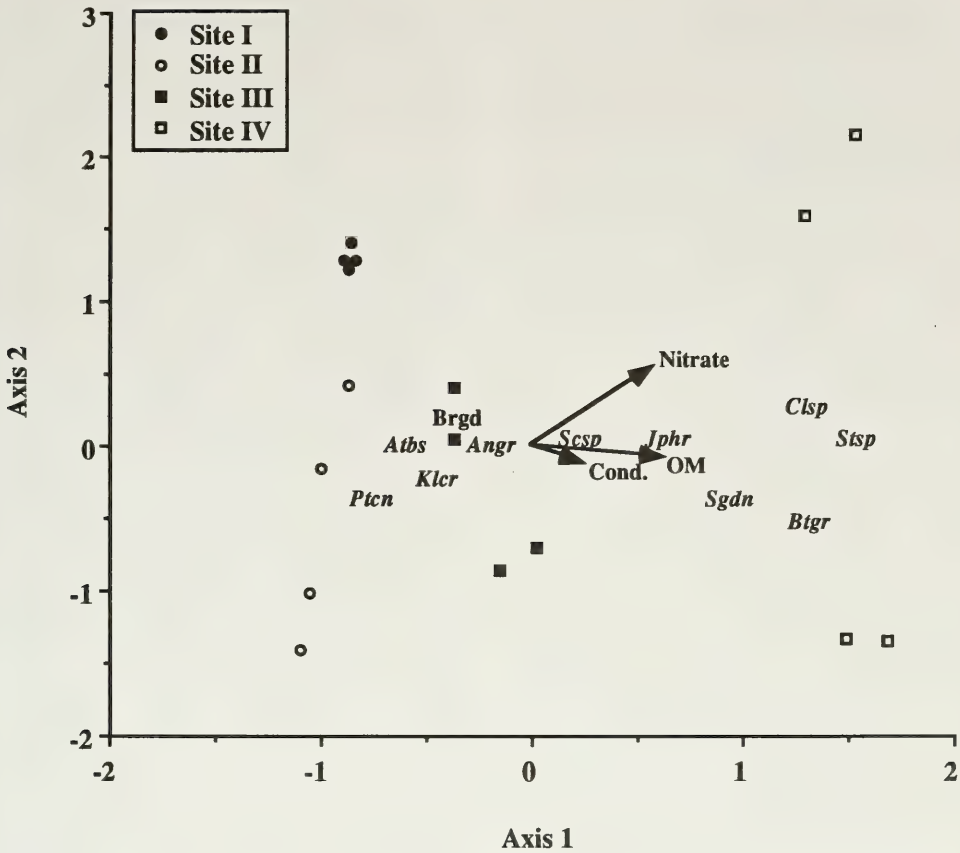


FIGURE 6. Canonical Correspondence Analysis (CCA) ordination of the mean cover of species with 3% or greater in at least one site in May and September of two subsequent years. Brgd — bare ground; Angr — *Andropogon gerardi*; Scsp — *Schizachyrium scoparium*; Atbs — *Artemisia biennis*; Btgr — *Bouteloua gracilis*; Clsp — *Cladonia* spp.; Jphr — *Juniperus horizontalis*; Klcr — *Koeleria cristata*; Ptcn — *Petalostemum candidum*; Sgdn — *Selaginella densa*; Stsp — *Stipa spartea*. Soil organic (OM), conductivity (Cond.), and nitrate were used as environmental variables in the analysis.

N, P and K. C_4 grasses are obligate mycotrophs whose level of dependence upon mycorrhiza is determined to some extent upon the nutrient status of the soil (Anderson et al. 1994). As in other sand hills (e.g., Hulett et al. 1966), many of the species are deeply rooted. The tap roots of *Chrysopsis villosa* may penetrate to 2.5 m, and roots of *Andropogon gerardi*, *Calamovilfa longifolia*, *Bouteloua gracilis*, and *Petalostemum* spp. may reach 1.5 to 2.0 m (Coupland and Johnson 1965). Some of these and other species (e.g., *Chrysopsis villosa*, *Andropogon gerardi*, *Artemisia frigida*, *Gaillardia aristata*) augment their deep tap roots with a broad network of branches near the soil surface (Coupland and Johnson 1965). In contrast, *Elymus canadensis*, *Koeleria cristata*, *Carex stenophylla*, and *Stipa spartea* have shallow, broadly spread roots (Weaver and Fitzpatrick 1932; Coupland and Johnson 1965).

In order to survive, the species found in Site I on the open dunes must be drought-resistant, and tolerant of abrasion, exposure, and burial. Some also serve to bind the sand and retard erosion. Both *Andropogon gerardi* and *Oryzopsis hymenoides* act in a limited way to trap and bind sand. Older clumps may be perched up to 1 m above the surrounding sand, also demonstrating their ability to withstand erosion around their dense bases and root system. Rhizomes of both species tolerated burial of 5 cm. Stems of *Lygodesmia juncea* and *Elaeagnus commutata* were excavated to depths of 2.5 to 3.0 m. Non-flowering plants such as *Selaginella densa*, mosses and lichens were not found on unstabilized sites because they are generally intolerant of burial (Coupland 1950; Birse et al. 1957; Oliver 1971). Many of the colonizing species produce wind-borne propagules. This suggests that, as in Israel (Kutiel et al. 1980), seed availability is not a limiting

factor in sand dune colonization. The harsh environmental conditions often cause high seedling mortality (Chadwick and Dalke 1965). Many seedlings of *Corispermum simplissimum* and *Helianthus petiolaris* were observed at Site I in the spring of the first year but did not survive. Maun (1981, 1985) concludes that *Calamovilfa longifolia* seedling mortality on Lake Huron sand dunes is due to high soil temperatures, desiccation, and burial by sand deposition. Weller (1989) showed that the emergence and seedling survival of *Lithospermum carolinense* on Lake Michigan dunes was reduced in areas of high sand deposition and that seedlings emerging from large nutlets had a better chance of survival when buried deeply (4–5 cm). Areas of active erosion and deposition are often colonized by rhizomatous species which use vegetative propagation to avoid the vulnerable seedling stage (Hulett et al. 1966; Kumler 1969; Maun 1985).

Changes in vegetation and soil with colonization

The increase in plant cover and numbers of species at each site with increasing colonization was similar to data from corresponding stages of colonization in other sand dunes in widely separated parts of the world; e.g., in Saskatchewan (Hulett et al. 1966), on the shores of Lake Huron (Baldwin and Maun 1983) and in Israel (Kuteil et al. 1980).

The literature shows that the early stages of colonization, are characterized by deep-rooted, usually warm season C_4 grasses. These may be "mound building" species such as *Ammophila breviligulata*, *Andropogon gerardii*, and *Calamovilfa longifolia* that have vigorous, branching rhizomes and are tall, robust, and able to overcome partial burial (Olson 1958; Barnes and Harrison 1982; Baldwin and Maun 1983; Yeaton 1988). Although tall grass species typically require a greater supply of soil moisture, their vigorous vegetative propagules and rhizomes aid in their establishment and spread in the harsh dune environment, even under condition of moderate sand accretion (Olson 1958; Maun 1985). Their highly branched, deep, fibrous root system efficiently exploits the ample available soil moisture at lower soil depths, their C_4 physiology making efficient use of this moisture, and their deep root system and bunched growth form anchors them in unstable sand.

Andropogon gerardi and *Koeleria cristata* were present in the early stages of colonization in this study, with a small amount of *Calamovilfa longifolia* present in Site II, while *Petalostemum candidum*, *Artemisia biennis* and *Solidago nemoralis* were notable herbs. Those with deep tap roots and an ability to grow vertically through sand (e.g., *Lygodesmia juncea*) were long-lived and often isolated pioneers. Species with both deep and surficial root networks (e.g., *Andropogon gerardi*, *Chrysopsis villosa*) helped to bind the sand, and promoted stabilization

and further colonization of the dunes (Coupland and Johnson 1965).

Shallow-rooted C_3 grasses such as *Stipa* were typical of later stages of colonization with finer textured soils and a higher water-holding potential (Barnes and Harrison 1982; Baldwin and Maun 1983). Their shallow roots rapidly deplete surface soil moisture due to high transpiration rates. This results in the lower soil moisture percentages of field capacity seen in Site IV, in spite of its greater water-holding capacity. Opportunistic, shallow-rooted species do not allow much moisture from sporadic rains to percolate down to deeper soil depths, thus out-competing tall grass species for available soil moisture in this xeric environment and displacing them in later stages of colonization (Barnes and Harrison 1982).

While C_4 plants, in general, are typical of earlier stages of colonization, and C_3 plants are typical of later stages, there are exceptions. *Koeleria* is a C_3 grass typical of early and intermediate stages of colonization, and *Bouteloua* is a C_4 grass typical of later stages (Kemp and Williams 1980; Barnes and Harrison 1982). The reasons for this are unclear although Barnes and Harrison (1982) suggest that *Koeleria* may not be able to compete with *Stipa* and *Bouteloua*, or may simply require open areas for successful seedling establishment. Incidentally, *Koeleria* is a component of grasslands in Saskatchewan in which *Stipa* and *Bouteloua* are dominant. Baldwin and Maun (1983) found that plant-soil moisture interactions were determining factors in species establishment and composition in sand dune habitats at various stages of colonization, rather than C_3 vs. C_4 physiology. Our study agrees with this conclusion.

In addition to *Bouteloua gracilis* and *Stipa spartea*, several taxa including *Juniperus horizontalis*, *Arctostaphylos uva-ursi*, *Carex* spp., and mosses and lichens have been found to be important in later stages of colonization (Olson 1958; Baldwin and Maun 1983). While the cover of *Arctostaphylos uva-ursi* in Site IV was low, that of *Juniperus horizontalis* was almost 10% and *Selaginella* and lichens combined had cover of almost 10%. Cyanobacteria and lichen fungal hyphae adhere to sand particles, binding them together. Moss rhizoids and lichen rhizines form a network around soil particles aggregating them. Comparatively low growing, inconspicuous plants such as lichens, mosses (Schulten 1985), and *Selaginella* are often overlooked, but they play a key role in the stabilization and aggregation of the sand surface, thus minimizing wind and water erosion. Additionally, they improve the micro-environmental conditions for the establishment of other species through the addition of soil organic matter and nutrients (Schulten 1985).

Soil organic content was significantly correlated with changes in species composition from early to

late stages of colonization. Organic content ameliorates the harsh soil conditions of sand dunes by increasing water and nutrient holding capacities. This is evident in the significant difference in soil moisture and nitrogen content of Site IV.

Summary

Successional processes from bare sand to prairie in the Bald Head Hills are characterized by an increase in species cover, species diversity and the complexity of the plant communities. In the dune system we sampled, plant cover increased from approximately 3% to 73% with a concomitant increase in taxa from 11 to 75. Some species occurred in more than one site. These changes were accompanied by an increase in soil organic matter, nutrients and water retention, a decrease in pH and moderated temperatures at the soil surface and to a depth of 30 cm.

The vegetation cover of the leading edge of the Bald Head Hills increased from 14% to 66% in 46 years. This was primarily due to the decrease in mobile sand to the northwest, the direction of the prevailing winds. Vegetation now almost entirely covers this portion of the Hills.

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APPENDIX. Taxa recorded in each sampling site.

Species	Common Name	Site I	Site II	Site III	Site IV
Vascular plants					
<i>Andropogon gerardii</i>	Big Bluestem	√	√	√	√
<i>Corispermum simplicissimum</i>	Bugseed	√	-	-	-
<i>Elaeagnus commutata</i>	Silverberry	√	√	√	-
<i>Elymus canadensis</i>	Canada Wild Rye	√	-	-	-
<i>Helianthus petiolaris</i>	Prairie Sunflower	√	-	-	-
<i>Lygodesmia juncea</i>	Skeleton Weed	√	√	√	-
<i>Oryzopsis hymenoides</i>	Indian Millet	√	√	√	-
<i>Petalostemum candidum</i>	White Prairie-Clover	√	√	√	-
<i>Rumex venosus</i>	Veined Dock	√	-	-	-
<i>Salix interior</i>	Sandbar-Willow	√	-	-	-
<i>Sporobolus cryptandrus</i>	Sand-Drop-Seed	√	-	-	-
<i>Bouteloua curtipendula</i>	Sideoats Grama	-	√	√	√
<i>Chrysopsis villosa</i>	Hairy Golden-Aster	-	√	√	√
<i>Grindelia squarrosa</i>	Curly-Gumweed	-	√	-	-
<i>Koeleria cristata</i>	June Grass	-	√	√	√
<i>Lesquerella ludoviciana</i>	Sand Badderpod	-	√	-	-
<i>Linum sulcatum</i>	Yellow Flax	-	√	√	√
<i>Melilotus alba</i>	White Melilot	-	√	-	-
<i>Melilotus officinalis</i>	Yellow Sweet Clover	-	√	-	-
<i>Schizachyrium scoparium</i>	Little Bluestem	-	√	√	√
<i>Senecio canus</i>	Silvery Groundsel	-	√	-	-
<i>Solidago nemoralis</i> var. <i>decemflora</i>	Snowy Goldenrod	-	√	√	√
<i>Townsendia exscapa</i>	Low Townsendia	-	√	-	-
<i>Artemisia biennis</i>	Biennial Wormwood	-	√	√	√
<i>Artemisia campestris</i> ssp. <i>caudata</i>	Plains Wormwood	-	√	√	√
<i>Calamovilfa longifolia</i>	Sand Grass	-	√	√	√
<i>Carex</i> spp., including:	Sedges	-	√	√	√
<i>Carex filifolia</i>	Thread-leaved Sedge	-	-	-	-
<i>Carex siccata</i>	Hay Sedge	-	-	-	-
<i>Carex stenophylla</i> var. <i>enervis</i>	Low Sedge	-	-	-	-
<i>Equisetum hyemale</i> var. <i>affine</i>	Common Scouring-rush	-	-	√	-
<i>Festuca ovina</i> var. <i>saximontana</i>	Sheep Fescue	-	√	√	√
Poaceae (Gramineae) spp.	Grasses	-	√	√	√
<i>Mamillaria vivipara</i>	Purple Cactus	-	-	√	-
<i>Oenothera biennis</i>	Evening-Primrose	-	-	√	-
<i>Oenothera nuttallii</i>	White Evening-Primrose	-	-	√	-
<i>Oxytropis lambertii</i>	Purple Locoweed	-	-	√	-
<i>Populus deltoides</i>	Cottonwood	-	-	√	-
<i>Rhus radicans</i> var. <i>rydbergii</i>	Poison Ivy	-	-	√	-
<i>Artemisia frigida</i>	Pasture Sage	-	-	√	√
<i>Bouteloua gracilis</i>	Blue Grama	-	-	√	√
<i>Juniperus communis</i>	Low Juniper	-	-	√	√
<i>Juniperus horizontalis</i>	Creeping Juniper	-	-	√	√
<i>Petalostemum purpureum</i>	Purple Prairie Clover	-	-	√	√
<i>Poa pratensis</i>	Kentucky Bluegrass	-	-	√	√
<i>Prunus virginiana</i>	Choke-Cherry	-	-	√	√
<i>Rosa arkansana</i>	Low Prairie Rose	-	-	√	√
<i>Rosa blanda</i>	Smooth Rose	-	-	√	√
<i>Stipa spartea</i>	Porcupine-Grass	-	-	√	√
<i>Achillea lanulosa</i>	Yarrow	-	-	-	√
<i>Allium stellatum</i>	Pink-flowered Onion	-	-	-	√

(Continued)

APPENDIX. *Continued*

Species	Common Name	Site I	Site II	Site III	Site IV
<i>Amelanchier alnifolia</i>	Saskatoon	-	-	-	√
<i>Androsace septentrionalis</i>	Pygmyflower	-	-	-	√
<i>Anemone cylindrica</i>	Long-fruited Anemone	-	-	-	√
<i>Anemone multifida</i>	Cut-leaved Anemone	-	-	-	√
<i>Anemone patens</i> var. <i>wolfgangiana</i>	Pasque-flower	-	-	-	√
<i>Antennaria neodioica</i>	Common Pussy-toes	-	-	-	√
<i>Arabis holboellii</i> var. <i>retrofracta</i>	Rock-Cress	-	-	-	√
<i>Artemisia ludoviciana</i> var. <i>gnaphalodes</i>	Prairie Sage	-	-	-	√
<i>Arctostaphylos uva-ursi</i>	Bearberry	-	-	-	√
<i>Asclepias viridiflora</i> var. <i>linearis</i>	Green Milkweed	-	-	-	√
<i>Aster ericoides</i>	Heath Aster	-	-	-	√
<i>Aster laevis</i>	Smooth Aster	-	-	-	√
<i>Aster ptarmicoides</i>	White Upland Aster	-	-	-	√
<i>Campanula rotundifolia</i>	Harebell	-	-	-	√
<i>Cerastium arvense</i>	Field Chickweed	-	-	-	√
<i>Chamaerhodos erecta</i> ssp. <i>nuttallii</i>	Chamaerhodos	-	-	-	√
<i>Chenopodium album</i>	Lamb's-quarters	-	-	-	√
<i>Comandra umbellata</i>	Bastard Toadflax	-	-	-	√
<i>Erigeron glabellus</i>	Smooth Fleabane	-	-	-	√
<i>Fragaria virginiana</i>	Smooth Wild Strawberry	-	-	-	√
<i>Gaillardia aristata</i>	Great-flowered Gaillardia	-	-	-	√
<i>Galium boreale</i>	Northern Bedstraw	-	-	-	√
<i>Geum triflorum</i>	Three-flowered Avens	-	-	-	√
<i>Helianthus laetiflorus</i> var. <i>subrhomboideus</i>	Beautiful Sunflower	-	-	-	√
<i>Heuchera richardsonii</i>	Alumroot	-	-	-	√
<i>Houstonia longifolia</i>	Long-leaved Bluets	-	-	-	√
<i>Lactuca pulchella</i>	Blue Lettuce	-	-	-	√
<i>Liatis punctata</i>	Dotted Blazingstar	-	-	-	√
<i>Lilium philadelphicum</i> var. <i>andinum</i>	Prairie Lily	-	-	-	√
<i>Linnaea borealis</i> var. <i>americana</i>	Twinflower	-	-	-	√
<i>Lithospermum canescens</i>	Puccoon	-	-	-	√
<i>Lithospermum incisum</i>	Narrow-leaved Puccoon	-	-	-	√
<i>Mirabilis nyctaginea</i>	Four-o'clock	-	-	-	√
<i>Moldavica parviflora</i>	Dragonhead	-	-	-	√
<i>Monarda fistulosa</i>	Wild Bergamot	-	-	-	√
<i>Muhlenbergia cuspidata</i>	Prairie Muhly	-	-	-	√
<i>Panicum wilcoxianum</i>	Sand Millet	-	-	-	√
<i>Penstemon gracilis</i>	Lilac-flowered Beardtongue	-	-	-	√
<i>Picea glauca</i>	White Spruce	-	-	-	√
<i>Poa compressa</i>	Wiregrass	-	-	-	√
<i>Polygala senega</i>	Seneca Snakeroot	-	-	-	√
<i>Populus tremuloides</i>	Aspen Poplar	-	-	-	√
<i>Potentilla arguta</i>	White Cinquefoil	-	-	-	√
<i>Potentilla pensylvanica</i>	Prairie Cinquefoil	-	-	-	√
<i>Prunus pumila</i>	Sand-Cherry	-	-	-	√
<i>Psoralea esculenta</i>	Breadroot	-	-	-	√
<i>Ranunculus rhomboideus</i>	Prairie-Buttercup	-	-	-	√
<i>Rudbeckia serotina</i>	Black-eyed Susan	-	-	-	√
<i>Selaginella densa</i>	Prairie Selaginella	-	-	-	√
<i>Symphoricarpos albus</i>	Snowberry	-	-	-	√

(Continued)

APPENDIX. *Concluded*

Species	Common Name	Site I	Site II	Site III	Site IV
Mosses		-	-	√	√
<i>Bryum</i> spp.		-	-	√	√
<i>Ceratodon purpureus</i>		-	-	√	√
<i>Tortula ruralis</i>		-	√	√	√
Lichens					
<i>Cetraria islandica</i>		-	-	√	√
<i>Cladonia</i> spp., including:		-	-	√	√
<i>C. cristatella</i>		-	-	-	-
<i>C. pyxidata</i> var. <i>pocillum</i>		-	-	-	-
<i>Peltigera rufescens</i>		-	-	√	√

Summer Habitat of Yellow Rails, *Coturnicops noveboracensis*, along the St. Lawrence River, Quebec

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As part of our investigations of Quebec birds at risk, we studied Yellow Rail (*Coturnicops noveboracensis*) habitats at three localities (Ile aux Grues, Cacouna and Lake Saint-François National Wildlife Area) along the St. Lawrence River, in southern Quebec, from 1993 to 1995. Circles, 0.2-ha in area, centred on six nests discovered at Ile aux Grues (the first nests reported east of Ontario in half a century), were characterized by herbaceous plants belonging to the Gramineae (*Spartina pectinata*), Cyperaceae (*Carex paleacea* and *C. horatodes*) or Juncaceae (*Juncus balticus*). All nesting habitats (circles) had very high mean percent cover of live vegetation. All also had a well-developed senescent vegetation canopy from the previous year's growth. Habitats used at Cacouna and Lake Saint-François National Wildlife Area were dominated by the same plant families, although the species varied among localities (*Carex paleacea*, *Scirpus maritimus*, and *Carex mackenziei* at Cacouna; *Carex lacustris*, *Calamagrostis canadensis*, and *Carex aquatilis* at Lake Saint-François National Wildlife Area). Each habitat usually had shallow (< 12 cm) or no measurable standing water, but the substrate remained water-saturated throughout the summer. Although *Carex* sedges predominated in each habitat, we found that other graminoid plant species provided important cover. In our view, *Carex* sedges should not be considered the only indicator plant species of Yellow Rail habitat; we believe instead that the Yellow Rail, in common with other rail species, may tolerate considerable variation in certain, subtle features of its summer habitat, such as plant species composition, stem density, or height of vegetation. Habitat selection may be influenced primarily by plant physiognomy and maximum water levels. We also believe that the presence of a concealing senescent vegetation canopy constitutes a specific feature of Yellow Rail breeding habitat.

Key Words: Yellow Rail, *Coturnicops noveboracensis*, nests, breeding habitat, Quebec.

Dans le cadre de nos travaux sur les oiseaux en péril, nous avons étudié les habitats utilisés par le Râle jaune (*Coturnicops noveboracensis*) à trois localités (Ile aux Grues, Cacouna et Réserve nationale de faune du Lac Saint-François) réparties le long du fleuve Saint-Laurent, dans le sud du Québec, de 1993 à 1995. Des cercles de 0.2 ha centrés sur six nids découverts à l'Ile aux Grues (les premiers nids découverts à l'est de l'Ontario depuis un demi-siècle) étaient dominés par des plantes graminoides faisant partie des Graminées (*Spartina pectinata*), Cypéracées (*Carex paleacea* et *C. horatodes*) et Juncacées (*Juncus balticus*). Tous avaient un couvert végétal très élevé, de même qu'un tapis formé par la végétation morte des années passées. Les habitats utilisés à Cacouna et à la Réserve nationale de faune du Lac Saint-François étaient dominés par des plantes graminoides des mêmes familles, bien que les espèces dominantes variaient selon les sites (*Carex paleacea*, *Scirpus maritimus* et *Carex mackenziei* à Cacouna; *Carex lacustris*, *Calamagrostis canadensis* et *Carex aquatilis* au Lac Saint-François). Dans tous les habitats, l'eau libre était le plus souvent absente ou peu profonde (≤ 12 cm), mais le sol demeurerait saturé d'eau au cours de l'été. Bien que les laïches (*Carex*) prédominaient dans chaque habitat, d'autres plantes graminoides constituaient un important couvert végétal. À notre avis, les laïches ne devraient pas être considérées comme les seules plantes indicatrices de l'habitat de nidification du Râle jaune. Nous croyons plutôt que le Râle jaune, à l'instar d'autres râles, peut tolérer des variations importantes de certains éléments de son habitat, comme la composition spécifique végétale, la densité des tiges et la hauteur de la végétation. La sélection de son habitat pourrait être influencée d'abord par la structure végétale et les niveaux d'eau maximums. La présence d'un tapis de végétation morte semble aussi constituer un élément caractéristique de l'habitat de nidification du Râle jaune.

Mots clés: Râle jaune, *Coturnicops noveboracensis*, nids, habitat de nidification, Québec.

Few detailed studies of the elusive Yellow Rail (*Coturnicops noveboracensis*) have been made, and most of these were conducted in the north-central and western United States—in North Dakota (Maltby 1915; Peabody 1922), Michigan (Walkinshaw 1939; Stenzel 1982; Bart et al. 1984; Bookhout and Stenzel 1987), Minnesota (Stalheim 1974), and Oregon (Stern et al. 1993; Popper and Stern 2000). Today, this rail remains one of the most poorly known birds in North America. Basic information, such as its breeding habitat, still needs to be documented, notably in the north-

eastern part of its range for which data are scant (Gibbs et al. 1991). In his comprehensive account of the Yellow Rail, Bookhout (1995) stated that future research should first try to "develop a better understanding of what constitutes acceptable breeding habitat and what does not, within the broad realm of marshes and wetlands."

Loss of wetlands to human activity is a major factor affecting railid populations (Eddleman et al. 1988; Stern et al. 1993; del Hoyo et al. 1996: 138). In the United States, the Yellow Rail is listed as a Migra-

tory Nongame Bird of Special Management Concern (USFWS 1995) and is considered a Species of Special Concern or Threatened Species in most states where it still breeds (North Dakota, Minnesota, Wisconsin, and Michigan). This rail is also considered a high-concern species in Canada (Dunn 1997), and was recently listed as a Vulnerable Species by the Committee on the Status of Endangered Wildlife in Canada (Alvo and Robert 1999*). In Quebec, it is considered vulnerable; not only is it rare in the province, but because of dike building, road construction, and agricultural activity, it also suffers from the draining of favourable habitat, especially along the St. Lawrence River, where at least 50% of such habitat has disappeared (Alvo and Robert 1999*).

As part of our investigations of Quebec birds at risk, we began conducting surveys along the St. Lawrence River in 1993 to document the distribution and ecology of the Yellow Rail. Since then, we have shown that Ile aux Grues, an island in the St. Lawrence corridor, is used as a breeding area (Robert and Laporte 1997) as well as a post-breeding staging area for males from elsewhere along the St. Lawrence corridor, sometimes hundreds of kilometres from the island (Robert and Laporte 1999). Six active nests were found there in 1994 and 1995; the first nests reported east of Ontario in half a century. Here, we describe Yellow Rail nest and habitat characteristics at Ile aux Grues; we describe habitat characteristics at two other localities in the St. Lawrence corridor—Cacouna and Lake Saint-François National Wildlife Area—where consistent numbers of Yellow Rails were found during our surveys; and we discuss these data in relation to the specific features that make a habitat potentially acceptable for breeding Yellow Rails (*sensu* Bookhout 1995).

Methods

Study area

We studied Yellow Rail habitats along the St. Lawrence River in southern Quebec from 1993 to 1995. From southwest to northeast along the river corridor, we worked at Lake Saint-François National Wildlife Area (NWA) (45°02'N, 74°32'W), Ile aux Grues (47°04'N, 70°33'W), and Cacouna (47°56'N, 69°31'W). These localities feature, respectively, 130, 530, and 30 ha of wet meadows that are inhabited by consistent numbers of calling Yellow Rails during the breeding season; significant numbers of males were banded there over the years (Robert and Laporte 1999). Ile aux Grues (a 20.4-km² island) and Cacouna are located in the upstream and downstream parts of the St. Lawrence Upper Estuary, respectively, whereas Lake Saint-François NWA lies

in the freshwater stretch of the St. Lawrence River proper (Figure 1). Zonation of shoreline vegetation differs in each of these sections of the St. Lawrence (St. Lawrence Centre 1996), as do the characteristic plant species found in high marshes (i.e., wet meadows) that are likely to be inhabited by Yellow Rails. Water characteristics and tidal range also differ along the St. Lawrence corridor: the water is fresh and there is no tidal influence in Lake Saint-François NWA; the water is brackish (approximately 5‰) and the mean spring high tide is about 7 m at Ile aux Grues, whereas the water is salty (approximately 28‰) and the mean spring high tide is about 5.5 m at Cacouna (St. Lawrence Centre 1996).

Nest and habitat characteristics at Ile aux Grues

We described each active nest discovered at Ile aux Grues in 1994 ($n = 4$) and 1995 ($n = 2$) (see Robert and Laporte 1997 for details on nest localization techniques) by taking the following measurements: outside diameter, inside diameter, depth of nest cup, nest height (depth), and nest distance from substrate. We also identified plants used for nest construction. Nesting habitat was described by randomly positioning 25, 0.07-m² circular plots in a 0.2-ha circle (radius, 25 m) centred on each nest. This 0.2-ha circle encompasses most of the area of movement by females during incubation and the first few days after hatching (Stenzel 1982). In each plot, we measured full height of vegetation from substrate (by extending the plant to full length), number of emergent stems, presence or absence of surface water, water depth, presence or absence of a senescent vegetation canopy from the previous year's growth, and height of this senescent vegetation canopy from substrate (without any manipulation). We also made ocular estimates of the percentage basal cover of the senescent vegetation canopy in each plot to the nearest 5%, as well as of the percentage basal cover of live vegetation using the following percent cover classes: <1, 1–5, 5–10, 10–25, 25–50, 50–75, >75. We calculated means using the mid-point of each cover class for each sample plot. Nesting habitat sampling was delayed until 27–30 July 1994 and 19–21 July 1995 in order to avoid jeopardizing nesting success.

Cacouna and Lake Saint-François NWA habitats

By sampling 0.07-m² circular plots and measuring the same variables as at Ile aux Grues (full height of vegetation, number of emergent stems, water depth, presence or absence of surface water, presence or absence of a senescent vegetation canopy, height of this canopy), we determined the habitat characteristics of areas used by Yellow Rails at Lake Saint-François NWA and Cacouna. At Lake Saint-François NWA, one plot was randomly positioned in each spot ($n = 15$) where a total of 11 individuals (rails) were captured or recaptured in May and June 1994 (see Robert and Laporte 1997 for details on

*See Documents Cited section

TABLE 1. Habitat characteristics in 0.2-ha circles centred on six Yellow Rail nests discovered at Ile aux Grues, Quebec, 1994-95.

Vegetation	Nest 1 (1994)				Nest 2 (1994)				Nest 3 (1994)				Nest 4 (1994)				Nest 5 (1995)				Nest 6 (1995)			
	Cover (%) ¹		Frequency (%)		Cover (%)		Frequency (%)		Cover (%)		Frequency (%)		Cover (%)		Frequency (%)		Cover (%)		Frequency (%)		Cover (%)		Frequency (%)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
<i>Spartina pectinata</i>	3.2	8.6	32	18.2	18.3	80	24.8	20.0	96	10.0	15.7	56	27.4	23.8	88	46.5	23.8	88	46.5	23.8	100	46.5	23.8	100
<i>Lythrum salicaria</i>	5.9	14.6	28	5.5	8.7	76	13.4	15.5	96	11.3	18.3	72	13.3	21.5	68	3.0	5.0	68	3.0	5.0	52	3.0	5.0	52
<i>Carex paleacea</i>	30.2	26.7	72	-	-	-	0.3	1.5	4	2.3	4.2	36	6.6	12.7	32	8.4	13.0	32	8.4	13.0	72	8.4	13.0	72
<i>Juncus balticus</i>	2.3	5.2	24	4.6	12.2	80	2.5	2.1	84	10.4	11.5	100	4.3	7.5	72	1.4	2.5	72	1.4	2.5	36	1.4	2.5	36
<i>Calamagrostis canadensis</i>	9.7	17.9	88	9.7	16.5	68	2.8	7.6	40	1.7	1.5	92	3.2	12.5	28	0.8	1.6	28	0.8	1.6	36	0.8	1.6	36
<i>Sanguisorba canadensis</i>	4.5	11.0	20	10.4	19.7	40	7.7	20.7	20	-	-	-	3.1	8.2	28	-	-	-	-	-	-	-	-	-
<i>Carex horridoides</i>	3.4	7.6	56	1.4	1.2	64	3.7	4.0	80	6.3	8.4	92	4.9	7.9	72	0.1	0.5	72	0.1	0.5	8	0.1	0.5	8
<i>Hierochloa odorata</i>	0.1	0.3	12	1.3	1.2	56	0.8	2.1	20	7.0	12.4	92	0.4	0.9	16	0.2	0.7	16	0.2	0.7	8	0.2	0.7	8
<i>Lycopodium</i> sp.	-	-	-	0.6	1.1	24	1.2	2.5	28	6.1	7.1	60	0.2	0.78	8	-	-	-	-	-	-	-	-	-
<i>Festuca rubra</i>	2.3	2.8	60	0.2	0.6	16	1.2	2.1	40	1.6	2.0	76	0.9	1.7	32	0.4	0.8	32	0.4	0.8	20	0.4	0.8	20
<i>Galium</i> sp.	0.1	0.3	12	0.7	0.9	48	2.0	1.9	80	1.4	1.6	72	0.5	0.8	40	0.9	1.0	40	0.9	1.0	52	0.9	1.0	52
<i>Menyanthes trifoliata</i>	2.0	4.3	28	2.1	4.2	32	1.8	4.1	24	-	-	-	0.7	3.5	4	-	-	4	-	-	-	-	-	-
<i>Potentilla</i> sp.	0.3	0.8	12	2.1	4.3	28	1.6	3.7	32	0.3	1.5	4	2.5	5.0	36	-	-	36	-	-	52	-	-	52
<i>Eleocharis halophila</i>	1.0	1.7	44	-	-	-	0.2	4	-	-	-	-	0.2	0.7	8	1.2	1.3	8	1.2	1.3	-	-	-	-
<i>Lathyrus maritimus</i>	0.1	0.3	8	0.7	1.0	36	0.7	1.0	44	0.3	0.6	20	0.5	1.6	16	-	-	16	-	-	-	-	-	-
	Mean	SD	Max.-Min.	Mean	SD	Max.-Min.	Mean	SD	Max.-Min.	Mean	SD	Max.-Min.	Mean	SD	Max.-Min.	Mean	SD	Max.-Min.	Mean	SD	Max.-Min.	Mean	SD	Max.-Min.
Total live vegetation (%)	77.5	14.4	87.5-37.5	80.5	11.5	87.5-62.5	77.5	12.5	87.5-62.5	76.5	17.8	87.5-37.5	67.5	17.7	87.5-37.5	66.5	21.3	87.5-37.5	66.5	21.3	87.5-37.5	66.5	21.3	87.5-37.5
Senescent canopy cover (%)	83.0	24.4	100-0	63.6	22.4	95-15	58.4	26.0	90-0	57.2	20.4	85-25	62.6	25.3	95-5	65.0	20.5	85-15	65.0	20.5	85-15	65.0	20.5	85-15
Number of plots (%) ²	-	-	96.0	-	-	100.0	-	-	92.0	-	-	92.0	-	-	100.0	-	-	100.0	-	-	100.0	-	-	100.0
Full height of stems (cm)	116.8	16.2	153-84	141.1	22.4	174-88	145.6	21.6	187-91	127.2	25.8	170-90	119.3	13.8	143-81	132.8	10.0	145-103	132.8	10.0	145-103	132.8	10.0	145-103
Number of stems per sq. m	1651.0	819.5	3233-699	1921.2	1366.4	7973-548	2073.5	730.9	3425-836	2910.2	1477.8	7644-1014	1401.0	651.5	3178-425	1109.6	386.0	2137-438	1109.6	386.0	2137-438	1109.6	386.0	2137-438
Height of senescent canopy (cm) ³	13.4	5.5	25-3	10.3	4.3	20-3	10.3	2.8	15-6	9.0	1.9	13-3	12.5	5.5	23-3	13.4	3.8	23-8	13.4	3.8	23-8	13.4	3.8	23-8
Surface water depth (cm) ³	2.1	1.2	5-1	1.8	1.0	3-1	1.5	1.2	4-1	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Number of plots (%) ²	-	-	80.0	-	-	16.0	-	-	24.0	-	-	4.0	-	-	-	-	-	-	-	-	-	-	-	-

¹Cover means are calculated from 25 plots per nest and include 0% cover when species is absent.
²Senescent canopy cover and surface water depth are followed by the % of plots (25/nest) in which the variable was present.
³Mean surface depths and mean senescent canopy heights do not include 0.

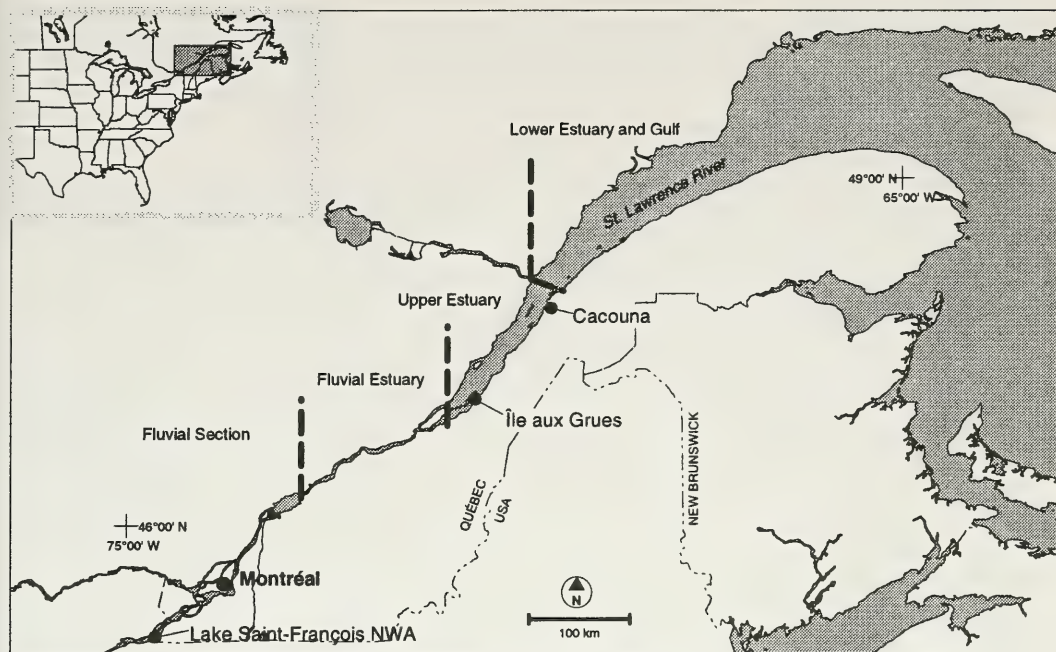


FIGURE 1. Yellow Rail study sites along the St. Lawrence River, Quebec.

capture techniques). At Cacouna, one plot was randomly positioned in each spot ($n = 34$) where a total of nine individuals were captured, recaptured, or located by radio-tracking in June and July 1993. Habitat sampling was delayed and took place on 1–2 September 1993 at Cacouna and 2–3 September 1994 in Lake Saint-François NWA. Although no nests were found at these two localities (Robert and Laporte 1997), we suspect that Yellow Rails do nest there because we heard several calling males while conducting our research and saw a female in each place (Robert and Laporte 1999).

We calculated the frequency of occurrence of plant species at each locality, including Ile aux Grues (all nests combined), on the basis of species dominance in each sampled plot. Contrary to the method used at Ile aux Grues (see above) and Cacouna (same procedure as for Ile aux Grues), vegetation sampling at Lake Saint-François NWA was done by identifying, in terms of basal cover, the dominant and sub-dominant species without making percentage estimates. We therefore converted the semi-quantitative percent cover classes found at Ile aux Grues and Cacouna to qualitative classes of dominance and sub-dominance similar to the ones found at Lake Saint-François NWA: in each plot, the plant species with the highest percentage basal cover was considered dominant, while the one with the second highest percentage basal cover was considered sub-dominant. At all sites, more than one plant

species could be classified dominant or sub-dominant in a plot (if they had the same semi-quantitative percent cover class), although the same species could never be dominant and sub-dominant in the same plot.

Water levels

From early June to September 1993, we regularly (generally weekly) measured standing water depth at 5 and 12 randomly selected stations at Ile aux Grues and Cacouna, respectively.

Results

Nest and habitat characteristics at Ile aux Grues

Nest ($n = 6$) dimensions were as follows: outside diameter 13.8 ± 1.2 cm (SD) (range 12–15), inside diameter 7.8 ± 0.8 cm (range 7–9), depth of nest cup 4.8 ± 1.7 cm (range 3–8), nest height (depth) 12.8 ± 3.1 cm (range 8–16), nest distance from substrate 3.0 ± 2.5 cm (range 0–6). Although it was impossible to identify all plants used for nest building, all nests were constructed, at least in part, with dead stems and leaves from the dominant species found in the vicinity. *Carex (paleacea and/or hormatodes)* stems were used for all nests, and *Spartina pectinata* and *Juncus balticus* were used for four and three nests, respectively. One nest (Nest 4, Table 1) was constructed with almost 100% *Juncus* stems. Other species used in nest building were *Hierochloa odorata* and *Eleocharis halophila*. All nests were directly covered by a senescent vegetation canopy. Mean

TABLE 2. Yellow Rail habitat characteristics at three localities along the St. Lawrence River corridor, Quebec.

	Cacouna (n = 34)	Ile aux Grues (n = 150)	Lake Saint-François NWA (n = 15)
Cyperaceae			
<i>Scirpus maritimus</i>	58.8	—	—
<i>Carex mackenziei</i>	32.4	—	—
<i>Eleocharis halophila</i>	29.4	6.0	—
<i>Carex paleacea</i>	61.8	32.0	—
<i>Carex hormatodes</i>	—	24.0	—
<i>Carex lacustris</i>	—	—	93.3
<i>Carex aquatilis</i>	—	—	33.3
Gramineae			
<i>Calamagrostis canadensis</i>	—	22.7	53.3
<i>Spartina pectinata</i>	—	62.7	—
<i>Hierochloe odorata</i>	—	11.3	—
<i>Festuca rubra</i>	—	10.0	—
Juncaceae			
<i>Juncus balticus</i>	14.7	29.3	—
<i>Juncus gerardii</i>	20.6	—	—
Other families			
<i>Lythrum salicaria</i>	2.9	44.0	6.7
<i>Sagittaria latifolia</i>	—	—	20.0
<i>Sanguisorba canadensis</i>	—	13.3	—
<i>Alnus</i> sp.	—	—	13.3
<i>Lemna</i> sp.	11.8	—	—
<i>Lycopus</i> sp.	2.9	10.7	—
<i>Potentilla</i> sp.	2.9	10.7	—
<i>Menyanthes trifoliata</i>	—	10.7	—
Number of plots with senescent canopy (%)	23.5	96.7	66.7 ¹
	<i>n</i> Mean (SD)	<i>n</i> Mean (SD)	<i>n</i> Mean (SD)
Full height of stems (cm)	34 91.7 (23.5)	150 130.5 (21.6)	15 143.7 (7.2)
Surface water depth (cm) ²	11 2.5 (1.8)	31 1.9 (1.1)	— —
Number of stems per sq. m.	34 3503.9 (2351.1)	150 1844.4 (1126.7)	15 782.8 (257.7)
Height of senescent canopy (cm) ²	8 9.9 (2.7)	145 11.5 (4.5)	10 18.3 (2.9)

¹This percentage does not include 4 plots burned. Only 10 plots (out of 15) had a senescent canopy because an area of Lake Saint-François NWA, where four rails were captured a few days earlier (see Discussion), was burned in May 1994.

²Mean surface water depths and mean senescent canopy heights do not include 0.

clutch size for the six nests was 8.8 ± 0.4 (range 8–9), and the mean number of eggs hatched was 8.2 ± 1.0 (range 7–9). The two shortest hatching times documented were 13.5 hours (7 eggs from a clutch of 9) and 19 hours (7 eggs from a clutch of 8).

All nesting habitats were characterized by herbaceous plants belonging mainly to the Gramineae, Cyperaceae or Juncaceae families (Table 1). In terms of mean percent cover, dominant and co-dominant plant species were *Spartina pectinata*, *Carex paleacea*, *Lythrum salicaria*, *Calamagrostis canadensis*, *Juncus balticus*, and *Sanguisorba canadensis*. Frequencies of occurrence were also high for other plant species, among which were *Carex hormatodes*, *Hierochloe odorata*, *Festuca rubra*, and *Eleocharis halophila* (Table 1). All nesting habitats had a very high mean percent cover of total live vegetation. All also had a well-developed senescent vegetation canopy; three had such a canopy in all their sampled plots, while the others had a canopy in at least 92% of their plots (Table 1). Surface water was completely

absent around (and under) both nests discovered in 1995, and mostly absent around three nests discovered in 1994, whereas the fourth nest (Nest 1, Table 1) found that year was mostly surrounded by water. Water depths around the four nests discovered in 1994 ranged from 1 to 5 cm (Table 1). Water depth under these nests averaged 1.3 ± 0.9 cm (range 0.5–2).

Cacouna and Lake Saint-François NWA habitats

Cacouna vegetation was dominated by herbaceous plants belonging to the Cyperaceae and Juncaceae, mainly *Carex paleacea*, *Scirpus maritimus*, *Carex mackenziei*, *Eleocharis halophila*, *Juncus gerardii*, and *Juncus balticus*. Lake Saint-François NWA was also characterized by herbaceous plants, mainly Cyperaceae and Gramineae i.e., *Carex lacustris*, *Calamagrostis canadensis*, and *Carex aquatilis* (Table 2). Some of the dominant species at Cacouna (*Carex paleacea*, *Juncus balticus*, and *Eleocharis halophila*) were the same as at Ile aux Grues. Height of vegetation, stem density, and height of vegetation canopy

varied from one location to another (Table 2). Cacouna had the lowest percentage (23.5%) of plots covered by a senescent vegetation canopy.

Water levels

From 9 June to 24 August 1993, standing water depths measured at Ile aux Grues varied from 0 to 22 cm ($n = 41$), although 90% were ≤ 12 cm and 39% were 0. Ile aux Grues water depths sometimes vary considerably depending on new moon and full moon (syzygy) tides, winds, and precipitation. For example, water depth rose from 7 to 43 cm in 45 minutes on the morning of 14 June 1995, in response to a full moon rising tide increased by northerly winds. Just as at Ile aux Grues, Cacouna water levels varied according to high tides and precipitation, but to a lesser degree as the area occupied by Yellow Rails was partly cut off from the St. Lawrence River by a dike. From 7 June to 15 September 1993, water depths measured at Cacouna varied from 0 to 19 cm ($n = 103$), although 92% were ≤ 12 cm and 17% were 0. On the basis of data recorded at Lake Saint-François NWA in July and August 1983, water depths in areas occupied by Yellow Rails varied from 5 to 20 cm (Canadian Wildlife Service, unpubl. data), according to precipitation and human water-level management operations (St. Lawrence Centre 1996). In each locality, the soil always remained water-saturated throughout the summer, even when there was no standing water.

Discussion

Yellow Rail habitats described during this study were large marshes dominated by fairly low graminoids (narrow-leaved linear emergent plants, mainly of the Cyperaceae, Gramineae, and Juncaceae families), where shallow or no measurable standing water was usually present, but where the substrate remained water-saturated throughout the summer. Apart from these general water conditions and vegetation features, characteristics of Yellow Rail habitat varied considerably among sites. The habitats described during this study were located in hydrographic environments which differ from one another: Cacouna was characterized by infrequent salt-water high tidal flooding, Ile aux Grues by infrequent brackish-water very high tidal flooding, and Lake Saint-François NWA by very poor drainage in a tide-free freshwater environment. This might explain most of the differences we found in plant species composition and, accordingly, in stem density, height of vegetation, and height of the senescent vegetation canopy. Still, previous studies conducted in Maine (Gibbs et al. 1991) and Michigan (Bookhout and Stenzel 1987) have also suggested that habitat variables (e.g., species composition and stem density) often differ from one location to another. Except for Lake Saint-François NWA, mean stem densities recorded during this study (1844–3504

stems/m²) were much higher than those calculated in Michigan (672–1398 stems/m²), which were in turn much higher than those recorded in Maine (85–150 stems/m²). These differences can probably be explained by the number, at Cacouna and Ile aux Grues, of plant species with very fine stems and leaves, such as *Juncus balticus*, *Carex mackenziei*, *Eleocharis halophila*, *Juncus gerardii*, *Carex hor-matodes*, and *Festuca rubra*, which were not found in most habitats described elsewhere. Lake Saint-François NWA habitat, on the other hand, consists mainly of graminoid plant species with larger stems and leaves i.e., *Carex lacustris*, *Calamagrostis canadensis*, and *Carex aquatilis*.

Although *Carex* sedges often characterize habitats used by Yellow Rails in summer (Bookhout and Stenzel 1987; Gibbs et al. 1991; Popper and Stern 2000; this study), we found that many other graminoid plants species may also dominate their habitat. The relative importance of *Carex* in Yellow Rail habitat may simply be due to the hydrophytic nature of the genus, its tendency to occupy shallow or damp areas and, more importantly, its extensive variation and distribution in temperate latitudes of North America (Marie-Victorin 1995). Because of this, we think that *Carex* sedges should not be considered the only indicator plant species of Yellow Rail habitat (Stenzel 1982: 4; Gibbs et al. 1991). We believe, instead, that the Yellow Rail, in common with other rail species, may tolerate considerable variation in certain, subtle features of its summer habitat, such as plant species composition, stem density, and/or height of vegetation (Rundle and Fredrickson 1981; Flores and Eddleman 1995; del Hoyo et al. 1996: 118; Taylor 1998). Habitat selection might be influenced primarily by plant physiognomy and maximum water levels. We also believe that the specific feature of Yellow Rail breeding habitat could be the presence of a senescent vegetation canopy. This canopy consists of the dry remains of the previous year's growth and is used to build and conceal the nest. In addition to the nests discovered during our research, all nests found by Dawson (1921), Peabody (1922), Devitt (1939), Walkinshaw (1939), Terrill (1943), Lane (1962), Elliot and Morrison (1979), Stenzel (1982), and Ritcher (in Robbins 1991: 240) in different parts of the United States and Canada were also covered by such a canopy. Moreover, from the 34 nests recently discovered in Oregon by Popper and Stern (2000), 26 had senescent canopies, five had live domes, and three had both. Although one of 12 nests discovered by Maltby (1915) was not covered in this manner, this concealing canopy would seem to be quite characteristic of Yellow Rail nesting habitat. Stenzel (1982: 37) suggested that a senescent vegetation canopy is important to habitat occupancy because it allows the Yellow Rails to move freely without being seen. The presence of such a canopy might be partic-

ularly important during the first weeks after the spring arrival of the rails, when the green vegetation has not yet grown enough to offer much concealment. It might also be important for the species' nesting success as females will pull the vegetation canopy back over the nest if disturbed (Stalheim 1974: 57; Stenzel 1982: 61; Bookhout 1995; M. Robert, personal observation); interestingly, the only active nest (out of eight) found by Popper and Stern (2000) that was visible from above without the vegetation being moved aside was the only one that failed.

A large part (about 40%) of the wet meadows at Ile aux Grues is subject to burning each spring and mowing each summer for agriculture. Other results obtained during our research (Robert and Laporte 1999) have shown that Yellow Rails use this particular part of the island, but only once the vegetation has grown; i.e., from mid-June onwards. There is also every indication that Yellow Rails do not use this particular part of the island for nesting (Robert and Laporte 1997, 1999). Indeed, all six nests described in this study were found in areas of Ile aux Grues not used for agriculture. In our opinion, Yellow Rails do not nest in wet meadows subject to agriculture precisely because these are not covered by a senescent vegetation canopy characteristic of the species' breeding habitat. As a matter of fact, we radio-tracked two Yellow Rails there in July and August 1993, and found that only 1.8% (1/55) of their locations had a senescent vegetation canopy (compared to 96.7% of plots sampled in nesting areas, Table 2). In other respects, the relatively low percentage of plots (23.5%) with a senescent vegetation canopy at Cacouna was not related to agriculture, but is probably explainable by the large proportion of plants there that do not always form such a canopy over the years, such as *Carex mackenziei*, *Eleocharis halophila*, *Juncus gerardii*, and *Juncus balticus*. On the contrary, dominant plant species found at Lake Saint-François NWA typically form a senescent canopy, and most plots (66.7%) sampled there had one. In fact, this percentage could even have been higher because one area (about 60 ha) of Lake Saint-François NWA was burned at the end of May 1994, and this contributed to the number of plots with senescent canopies being underestimated. (We had captured four Yellow Rails in that area a few days before the fire, and had to sample the vegetation there in September so some plots were not covered by a senescent canopy simply because of the fire.) Concerning the effect of fire on the birds themselves, we noted that no Yellow Rails were present in that area on 6 June 1994, but one was recaptured about 350 m away in an adjacent unburned area. This rail and another one (first capture) were in the burned area on 30 June 1994, when the vegetation had grown back. Another 50 ha of the NWA was burned in April 1995, and although we surveyed it on three occasions in May 1995 and heard many rails in

an adjacent unburned area (the one burned in May 1994), no Yellow Rails were found. According to these observations, in addition to our other results and to Savaloja's experience (1981: 80), we suggest that Yellow Rails do not use freshly burned marshes, until the green vegetation has grown sufficiently to offer the birds concealment. Furthermore, and contrary to Stalheim's assumption (1974: 12), we think that because fire destroys the senescent vegetation canopy, burned areas are not usable for nesting by Yellow Rails until the first or second spring after a fire, depending upon whether the fire occurred in the spring or in the fall.

The water depths measured at Ile aux Grues indicated that water levels varied mainly according to high tides and precipitation, deeper standing water being present there mainly during the full moon and a few days thereafter or after heavy rainfalls. Moreover, even though water depths were almost always ≤ 12 cm, we measured some others that were much deeper, particularly during new moon and full moon tides. Two of the nests discovered at Ile aux Grues were 16 cm deep (from the top to the bottom of the nest) and two others were 13 cm deep. Based on Bookhout (1995), these are the deepest Yellow Rail nests ever reported, and we suggest that such nests may help the species in coping with water-level fluctuations, as occurs at Ile aux Grues. This may also help explain why Yellow Rail females continue to add material to their nests throughout incubation (Stalheim 1974: 38; M. Robert, personal observation). Nevertheless, we agree with Bookhout (1995) that some nests may get flooded at times, as happens with Black Rails (*Laterallus jamaicensis*) (Ingersoll 1909), and we believe that this might be a regular occurrence along the St. Lawrence River Upper Estuary, where tide amplitude is very high.

This study substantiates the breeding of the Yellow Rail in eastern Canada (east of Ontario) for the first time in half a century and presents habitat descriptions for that species. Our characterization of Yellow Rail habitat at different localities along the St. Lawrence River indicates that this bird inhabits large marshes dominated by fairly low graminoid species, mainly sedges, grasses, and rushes, usually with shallow or no measurable standing water, but invariably with water-saturated substrate. According to this study and others, there is also every indication that the presence of a concealing canopy of senescent vegetation is a specific feature of Yellow Rail nesting habitat. Apart from these general water conditions and features of vegetation structure, characteristics of Yellow Rail habitat can vary considerably among locations.

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Diversity of Forest Upland Arachnid Communities in Manitoba Taiga (Araneae, Opiliones)

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Aitchison, C. W., and Glenn D. Sutherland. 2000. Diversity of forest upland arachnid communities in Manitoba taiga (Araneae, Opiliones). *Canadian Field-Naturalist* 114(4): 636–651.

The diversity of taiga upland arachnid communities, collected mainly in pitfall or pan traps, is compared among forested habitats in two Manitoba regions, one southern and one northern. In the south, where collections were taken both in summer and in winter under the snow cover, the dominant spider families were Erigonidae, Linyphiidae, Lycosidae, and Gnaphosidae. The diurnal and nocturnal pursuit guilds dominated across habitats. In the north, with summer collecting only, dominant families were Lycosidae, Gnaphosidae and Erigonidae of the diurnal pursuit guild. The southern taiga uplands had 99 species of spiders, northern uplands 49 species with 19 species common to both regions. The five most dominant species from these families are *Agroeca ornata* Banks, *Gnaphosa microps* Holm, *Pardosa xerampelina* (Keyserling), *P. mackenziana* (Keyserling), and *Agelenopsis utahana* (Chamberlin and Ivie). Three opiloid species occur in the south and one species, *Odiellus pictus* Wood, occurs in both regions. In this region of the taiga, we found the most species-rich habitats to be undisturbed forest types, i.e., alder-tamarack ecotone in winter, which produced 34 winter-active species (n=233), with 27 species collected only during winter months. Among-habitat differences in species richness, species dominance and guild composition suggests that maintenance of habitat heterogeneity is needed at all scales to preserve the diversity of forest floor arachnid communities in managed taiga forests.

Key Words: spiders, arachnids, Opiliones, Araneae, uplands, taiga, forest, diversity, subnivean activity.

The temperate taiga covers about 34% of the land area of Canada, and accounts for over 75% of all forested land in Canada (Schmiegelow et al. 1997), with dominant species of Black Spruce, *Picea mariana*, and White Spruce, *Picea glauca*. Taiga is a Russian word meaning boreal or northern coniferous forest; for simplicity's sake, taiga is used here. Those species within the taiga will be referred to as boreal. Despite its importance as a major terrestrial ecosystem, information on the composition and functioning of the boreal forest arachnid community remains sketchy. In Canada there are about 1400 species of spiders, with approximately another 20% yet to be described (Dondale 1979); within the taiga of Manitoba 154 species of spiders are known (Aitchison-Benell 1994; the data from this paper). A summer survey of the spider fauna in six different northern boreal forest habitats was conducted by Freitag et al. (1982), where 57 species in 13 families were collected over a three-month period. Aitchison-Benell (1994) reported on the spider communities of taiga bogs in Manitoba. Much less is known about the winter-active boreal forest spider fauna either in Europe or in North America. Huhta (1965) reported those spiders taken from litter under permanent winter snow cover in Finland, although the species were not necessarily winter-active. Olynyk and Freitag (1977) reported four species in three families collected over the winter months in mixed spruce forest in northwestern Ontario.

Spiders in taiga bog habitats have been studied in Europe (Koponen 1979; Palmgren 1972; Schikora 1994) and in North America (Koponen 1994; Dondale and Redner 1994; Aitchison-Benell 1994). Drier upland habitats of the taiga have also been studied in Finland (Huhta 1965; Palmgren 1972; Hippa and Mannila 1974; Palmgren and Biström 1979; Biström and Väisänen 1988; Väisänen and Biström 1990; Niemela et al. 1996), Norway (Hauge 1977), Sweden (Pettersson 1996), Russia (Eskov 1981), Siberia (Koponen and Marusik 1992) and North America (Hillburn and Jennings 1988; Jennings et al. 1988). In Finland spruce forests are basically classified as the Myrtillus type (MT) (mesic forest with *Vaccinium myrtillus* and mosses) or the Vaccinium type (VT) (more xeric, open forest with *V. vitis-idaea* L., lichens and a few mosses (Huhta 1965; Palmgren 1972). Only the more mesic areas have larger numbers of individuals/m² (especially Linyphiidae and Erigonidae) than do drier sites (Huhta 1965). For forest-floor spider species, "The presence or absence of moss cover in the biotope is the most important as far as differentiation of spider populations is concerned" (Eskov 1981), while for arboreal species old-growth, lichen-rich forest types appear to contain the most diverse fauna (Pettersen 1996). Communities of ground-dwelling arthropods (including Araneae) in taiga forests appears to be characterized by substantial heterogeneity in species composition at all scales ranging from the regional scale down to the local

scales of the activity radii of individual species (Niemela et al. 1996).

The majority of spiders collected in taiga forests belong to the families Linyphiidae, Erigonidae (Huhta 1965; Palmgren 1972; Hippa and Mannila 1974; Hauge 1977; Palmgren and Biström 1979; Eskov 1981; Biström and Väisänen 1988; Jennings et al. 1988; Väisänen and Biström 1990; Koponen and Marusik 1992). Other families are Theridiidae, Lycosidae, Gnaphosidae, Thomisidae, Philodromidae, Araneidae and Clubionidae (Huhta 1965; Palmgren 1972; Hippa and Mannila 1974; Palmgren and Biström 1979; Eskov 1981; Biström and Väisänen 1988; Jennings et al. 1988; Väisänen and Biström 1990; Koponen and Marusik 1992). Collection methods in these studies include pitfall trapping, sieved quadrat samples (Huhta 1965; Hauge 1977; Palmgren and Biström 1979; Eskov 1981; Hillburn and Jennings 1988; Jennings et al. 1988; Väisänen and Biström 1990), as well as sweeping, trunk samples and hand picking (Hippa and Mannila 1974; Väisänen and Biström 1990; Koponen and Marusik 1992).

Spiders represent a large percentage of arthropod predator biomass in temperate forests (Moulder and Reichle 1972; Petersen and Luxton 1982), and are capable of regulating populations of soil arthropods (Clarke and Grant 1968). Because spiders are relatively easy to sample and identify, they are potentially useful as indicator organisms of habitat and ecosystem function (McIver et al. 1992). Adult spiders may be taken to species, while this is not possible for juveniles. Consequently juveniles are excluded from this study. Increased demands placed on boreal forests for pulpwood and timber supply (Bonnor 1985) caused by human disturbance can potentially and gradually shift forest species composition and simplify forest habitat structure. Therefore, assessment of current spider diversity in typical boreal forest habitats is an important step in developing comprehensive biodiversity indicators for boreal forests.

The objective of this research is to describe and compare the species composition of the spiders and opilionid fauna and their distribution patterns within several common upland habitat types in both southern and northern Manitoba. In general, between site and habitat comparisons will be made here, using data collected during the snow-free period. For the southern region some information on winter-active species is also included.

Methods

The taiga comprises a large part of the province of Manitoba and has four subdivisions from south to north: (1) mixed forest; (2) taiga (pure boreal or northern coniferous forest); (3) tundra-taiga transition; and (4) subarctic forest-tundra along the

Hudson Bay coast. Two study areas were chosen in the taiga zone.

The southern study area was located at Taiga Biological Station (TBS) at 51°02' N, 95°20' W in the permafrost-free zone of the Manitoba taiga. The climate at TBS has a mean January temperature of -21.3°C, a mean July temperature of +18.8°C, and a mean annual precipitation of 423 mm (Wood et al. 1977). The northern study area was located at Southern Indian Lake (SIL), a large hydroelectric reservoir located at 56°47' N, 98°56' W in the discontinuous permafrost zone of the northern Manitoba taiga. At SIL the mean January temperature is -26.5°C, the mean July temperature is +16.0°C, and the mean annual precipitation is 430 mm (Newbury et al. 1984).

Summer sampling in both study areas was done using pitfall traps (9 cm deep, 7 cm diameter), made of plastic cups and half-filled with a 1:1 mixture of ethylene glycol and water placed in transects of 6 traps, 5 m apart. The pitfall traps had their upper lip level with the soil surface. Traps were covered by a half cylinder of asphalt shingle to repel rain. At TBS the traps were sampled approximately every three weeks from early June to early October 1987. Where vegetation permitted, sweeping of low bushes and beating of trees was also done.

At TBS, a total of seven forest upland habitats were sampled: (1) an Alder-Ridge ecotone (hereafter called AR-EC) between bog and forest with overstory dominated by mixed *Picea glauca* and *Picea mariana*, and understory dominated by *Alnus* spp. and *Salix* spp.; (2) an Alder-Tamarack ecotone (AT-EC) between bog and forest with overstory dominated by mixed *Larix laricina*, *P. mariana* and *P. glauca* with understory of *Alnus* spp.; (3) Aspen Upland (AS-UP) mixed forest with *Populus tremuloides* and *Betula papyrifera* making up 30–70% of the overstory with *P. glauca* and *Abies balsamea* comprising the remainder; (4) freshly burned Jack-Pine Ridge (JPR-F); (5) mature Jack-Pine Ridge (JPR-M); (6) old growth Jack-Pine Ridge (JPR-O) containing almost pure *Pinus banksiana* as overstory and *Amelanchier alnifolia*, *Vaccinium* spp., *Juniperus horizontalis*, and *Arctostaphylos uva-ursi* as common shrubs; (7) Jack-Pine Sand Plain (JP-SP) with pure *Pinus banksiana* again as overstory and *Vaccinium vitis-idea* and *Linnaea borealis* as common shrubs (Schaefer and Pruitt 1991). The fresh burn occurred in 1987 while the old growth had not burned since at least the turn of the century (Schaefer 1993). Four of these habitats were also sampled during the winter: Alder-Tamarack ecotone; Aspen-Upland; old growth Jack-Pine Ridge; and Jack-Pine Sand Plain. Winter was defined as the period from November to mid-April (Aitchison 1978). Samples were collected at monthly intervals from November 1975 to April 1976 and from November 1978 to April 1979 using the same

TABLE 1. Species of spiders and opilionids from forest upland sites at TBS and SIL in Manitoba. Families and species are presented phylogenetically. Species presence at each study area is indicated by a '+'. An asterisk indicates subnivean species captured during winter months (November-April). See text for sources for guild designations.

Species	Guild ¹	TBS	SIL
Dictynidae			
<i>Lathys pallida</i> (Marx)	HB	+	
Amaurobiidae			
* <i>Amaurobius borealis</i> Emerton	HB	+	
* <i>Arctobius agelenoides</i> (Emerton)	HB	+	
* <i>Cybaeopsis euoplus</i> (Bishop & Crosby)	HB	+	+
* <i>C. tibialis</i> (Emerton)	HB	+	
Theridiidae			
* <i>Robertus fuscus</i> (Emerton)	SL	+	
<i>Theridion petraeum</i> L. Koch	SL		+
* <i>Theridion</i> sp.	SL	+	
Linyphiidae			
* <i>Allomengea pinnata</i> (Grübe)	SW	+	
* <i>Bathyphantes pallidus</i> (Banks)	SW	+	
* <i>Centromerus longibulbus</i> (Emerton)	SW	+	
* <i>C. persolutus</i> (O.P.-Cambridge)	SW	+	
* <i>Eulaira</i> sp.	SW	+	
* <i>Helophora insignis</i> (Blackwall)	SW	+	
* <i>Lepthyphantes alpinus</i> (Emerton)	SW	+	
* <i>L. complicatus</i> (Emerton)	SW	+	
* <i>L. intricatus</i> (Emerton)	SW	+	
<i>L. turbatrix</i> (O.P.-Cambridge)	SW		+
* <i>L. zebra</i> (Emerton)	SW	+	
* <i>Lepthyphantes</i> sp.	SW	+	
* <i>Macrargus multesimus</i> (O.P.-Cambridge)	SW	+	
<i>Meioneta simplex</i> (Emerton)	SW	+	
* <i>Microneta viaria</i> (Blackwall)	SW	+	+
* <i>Neriene clathrata</i> (Sundevall)	SW	+	
<i>N. radiata</i> (Walckenaer)	SW		+
* <i>Oreonetides recurvatus</i> (Emerton)	SW	+	
* <i>Oreonetides</i> sp. nr. <i>flavus</i>	SW	+	
<i>Pityohyphantes phrygianus</i> (C.L. Koch)	SW		+
<i>Porrhomma terrestris</i> (Emerton)	SW		+
* <i>Porrhomma</i> sp.	SW	+	
Erigonidae			
<i>Ceraticelus fissiceps</i> (O.P.-Cambridge)	SW	+	
<i>C. laetus</i> (O.P.-Cambridge)	SW	+	
<i>C. minutus</i> (Emerton)	SW	+	
<i>Dicymbium elongatum</i> (Emerton)	SW	+	
* <i>Diplocentria bidentata</i> (Emerton)	SW	+	
* <i>Entelecara</i> sp.	SW	+	
<i>Erigone atra</i> Blackwall	SW	+	
* <i>Eulaira</i> sp.	SW	+	
<i>Grammonota augusta</i> Dondale	SW	+	+
<i>G. gigas</i> (Banks)	SW	+	
<i>G. pictilis</i> (O.P.-Cambridge)	SW	+	
<i>Hybauchenidium cymbadentatus</i> (Crosby & Bishop)	SW	+	
* <i>H. gibbosum</i> (Sørensen)	SW	+	
* <i>Hybauchenidium</i> sp.	SW	+	
<i>Hypselistes florens</i> (O.P.-Cambridge)	SW		+
<i>Lophomma sylvaticum</i> (Emerton)	SW	+	
<i>Oedothorax trilobatus</i> (Banks)	SW	+	
<i>Pelecopsis mengei</i> (Simon)	SW		+
* <i>Pocadicnemis americana</i> Millidge	SW	+	+
* <i>Sciastes truncatus</i> (Emerton)	SW	+	
<i>Scotinotylus pallidus</i> (Emerton)	SW	+	
<i>Sisicottus montanus</i> (Emerton)	SW		+
* <i>Sisicus apertus</i> (Holm)	SW	+	

Continued

TABLE 1. (Continued).

Species	Guild ¹	TBS	SIL
<i>Sougambus bostoniensis</i> (Emerton)	SW	+	
* <i>Sougambus</i> sp.	SW	+	
<i>Tapinocyba minuta</i> (Emerton)	SW	+	
* <i>T. simplex</i> (Emerton)	SW	+	
* <i>Tapinocyba</i> sp.	SW	+	
<i>Tunagyna debilis</i> (Banks)	SW	+	
<i>Vermontia thoracica</i> (Emerton)	SW	+	
<i>Wabasso cacuminatus</i> Millidge	SW	+	
<i>Walckenaeria atrotibialis</i> O.P.-Cambridge	SW	+	
* <i>W. castanea</i> (Emerton)	SW	+	+
* <i>W. directa</i> (O.P.-Cambridge)	SW	+	
<i>W. exigua</i> Millidge	SW	+	
* <i>Walckenaeria</i> sp.	SW	+	
Araneidae			
<i>Nuctunea patagiata</i> (Clerck)	OW		+
Tetragnathidae			
<i>Tetragnatha versicolor</i> Walckenaer	OW		+
* <i>Tetragnatha</i> sp.	OW	+	
Agelenidae			
<i>Agelenopsis utahana</i> (Chamberlin & Ivie)	WL	+	+
* <i>Cicurina brevis</i> (Emerton)	WL	+	
* <i>C. robusta</i> Simon	WL	+	
* <i>Coras montanus</i> (Emerton)	WL	+	
<i>Cybaeota calcarata</i> (Emerton)	WL	+	
Hahniidae			
<i>Antistea brunnea</i> (Emerton)	WL	+	
* <i>Hahnia cinerea</i> Emerton	WL	+	
* <i>H. inornata</i> Chamberlin & Ivie	WL	+	
<i>Neoantistea agilis</i> (Keyserling)	WL	+	+
Mimetidae			
* <i>Ero canionis</i> Chamberlin & Ivie	PS	+	
Lycosidae			
<i>Alopecosa aculeata</i> (Clerck)	DP	+	+
<i>Arctosa alpigena</i> (Doleschall)	DP		+
<i>A. rubicunda</i> (Keyserling)	DP	+	+
<i>Hogna frondicola</i> (Emerton)	DP	+	
<i>Pardosa furcifera</i> (Thorell)	DP		+
<i>P. hyperborea</i> (Thorell)	DP	+	+
* <i>P. mackenziana</i> (Keyserling)	DP	+	+
<i>P. moesta</i> Banks	DP	+	+
<i>P. xerampelina</i> (Keyserling)	DP	+	+
<i>Pirata bryantae</i> Kurata	DP	+	
<i>P. insularis</i> Emerton	DP	+	
<i>P. minutus</i> Emerton	DP	+	+
* <i>Trochosa terricola</i> Thorell	DP	+	+
Gnaphosidae			
<i>Drassodes neglectus</i> (Keyserling)	NR	+	
<i>Gnaphosa brumalis</i> Thorell	NR		+
<i>G. microps</i> Holm	NR	+	+
* <i>G. muscorum</i> (L. Koch)	NR	+	+
<i>Haplodrassus eunis</i> Chamberlin	NR	+	
<i>H. hiemalis</i> (Emerton)	NR		+
<i>H. signifer</i> (C.L. Koch)	NR	+	
<i>Herphyllus ecclesiasticus</i> Hentz	NR	+	
<i>Micaria aenea</i> Thorell	NR	+	+
<i>M. pulicaria</i> (Sundevall)	NR	+	+
<i>M. tripunctata</i> Holm	NR		+
* <i>Zelotes fratris</i> Chamberlin	NR	+	+
<i>Z. puritanus</i> Chamberlin	NR		+

Continued

TABLE 1. (Concluded).

Species	Guild ¹	TBS	SIL
Liocranidae			
* <i>Agroeca ornata</i> Banks	NR	+	+
* <i>Phrurotimpus borealis</i> (Emerton)	NR	+	
* <i>Scotinella pugnata</i> (Emerton)	NR	+	
Clubionidae			
<i>Clubiona canadensis</i> Emerton	DR		+
<i>C. furcata</i> Emerton	DR		+
<i>C. gertschi</i> Edwards	DR	+	
<i>C. kulczynskii</i> Lessert	DR	+	+
Thomisidae			
<i>Misumena vatia</i> (Clerck)	DA		+
* <i>Ozyptila sincera canadensis</i> Dondale & Redner	DA	+	
<i>Xysticus chippewa</i> Gertsch	DA		+
<i>X. elegans</i> Keyserling	DA	+	
<i>X. ellipticus</i> Turnbull, Dondale & Redner	DA	+	
<i>X. emertoni</i> Keyserling	DA		+
<i>X. obscurus</i> Collett	DA		+
Philodromidae			
<i>Philodromus cespitum</i> (Walckenaer)	DR		+
<i>Philodromus histrio</i> (Latrielle)	DR		+
Salticidae			
<i>Eris militaris</i> (Hentz)	DS		+
<i>Evarcha hoyi</i> (Peckham & Peckham)	DS	+	
<i>Habrocestum pulex</i> (Hentz)	DS	+	
<i>Neon nelli</i> Peckham & Peckham	DS	+	
<i>Phidippus borealis</i> Banks	DS		+
<i>Tutelina similis</i> (Banks)	DS	+	
Opiliones: Sclerosomatidae			
<i>Leiobunum calcar</i> (Wood)		+	
<i>L. vittatum</i> (Say)		+	
Phalangiiidae			
<i>Odiellus pictus</i> (Wood)		+	+

¹DA, diurnal ambush; DP, diurnal pursuit; DR, diurnal running; DS, diurnal stalking; HB, hackled band; NR, nocturnal running; OW, orb weavers; PS, pirate spiders; SL, scattered line; SW, sheet web; and WL, web-line.

transect sampling scheme with traps covered by a ring and lid to exclude snow (see Aitchison 1974 for a description of the collection method; Pruitt 1973, for video of the method in use).

At SIL, transects were set up in early July 1987 and emptied either 5 or 6 days later. All of the SIL transects had underlying permafrost. Sweeping of low vegetation and beating of bushes and trees was done as well. Five upland habitats were sampled at SIL: The camp site (C) had a mixed, semi-open canopy of *Populus tremuloides* and *Pinus banksiana*, a shrub layer of *Alnus* spp. and an understory of *Vaccinium* spp. with much litter and little moss. The Long Bay (LB) upland had a mixed deciduous, semi-open overstory of *Picea mariana* and *Betula papyrifera* and an understory of *Vaccinium* spp., grasses, and *Arctostaphylos* spp. The Opach site (OP), South Bay (SB) and Swan Bay (SWB) sites were similar shoreline areas, each with a semi-open overstory of *P. mariana*, some *Salix* spp. and *Alnus* spp., and an understory of *Sphagnum* spp., *Oxycoccus macrocarpus*, and *Ledum groenlandicum*.

Material collected from traps was filtered, rinsed in water, and placed in 70% ethanol. Sweep material was placed directly into 70% ethanol. For each site in the two localities, all specimens were sorted and identified to species in the laboratory. Problematic specimens were sent to C. D. Dondale and J. H. Redner for determination, some of which were retained for the Canadian National Collection. Other specimens are in the personal collection of C. W. Aitchison.

Community Composition

Because both pitfall trap samples and sweep samples are better estimators of activity rather than density (McIver et al. 1992), and because of differing sampling intensities at the two localities, we make no statements about absolute abundances *per se*. Rather we examined patterns in our arachnid fauna in three ways:

1. *Species Dominance*. Palmgren (1972) devised a species classification method in which dominant species account for > 10% of total species, subdominants for 5–10%, and influents for 2–5% of species.

TABLE 2. The number of spider species and specimens in each family taken from the seven forest upland sites at TBS. Seasonal data are combined, as well as presented separately. Families are listed in descending order of overall abundance of specimens. Percentages are shown in brackets.

Family	Overall				Summer				Winter			
	Species	%	Specimens	%	Species	%	Specimens	%	Species	%	Specimens	%
Lycosidae	12	(12.4)	555	(39.8)	11	(15.3)	547	(53.4)	2	(4.0)	8	(1.9)
Erigonidae	31	(32.0)	209	(15.0)	23	(31.9)	132	(12.9)	14	(28.0)	77	(20.7)
Liocranidae	3	(3.1)	194	(13.9)	3	(4.2)	22	(2.1)	3	(6.0)	172	(46.2)
Linyphiidae	15	(15.5)	142	(10.2)	7	(9.7)	85	(8.3)	15	(30.0)	57	(15.3)
Hahniidae	4	(4.1)	115	(8.2)	3	(4.2)	113	(11.0)	2	(4.0)	2	(0.5)
Gnaphosidae	9	(9.3)	85	(6.1)	8	(11.1)	79	(7.7)	2	(4.0)	6	(1.6)
Agelenidae	5	(5.2)	39	(2.8)	4	(5.6)	16	(1.6)	3	(6.0)	23	(6.2)
Amurobiidae	5	(5.2)	25	(1.8)	2	(2.8)	5	(0.5)	5	(10.0)	20	(5.4)
Thomisidae	3	(3.1)	9	(0.6)	3	(4.2)	9	(0.9)	-	-	-	-
Salicidae	4	(4.1)	7	(0.5)	4	(5.6)	7	(0.7)	-	-	-	-
Theridiidae	1	(1.0)	6	(0.4)	1	(1.4)	1	(0.1)	2	(4.0)	5	(1.3)
Clubionidae	2	(2.1)	3	(0.2)	2	(2.8)	3	(0.3)	-	-	-	-
Dictynidae	1	(1.0)	3	(0.2)	1	(1.4)	3	(0.3)	-	-	-	-
Tetragnathidae	1	(1.0)	2	(0.1)	-	-	-	-	1	(2.0)	2	(0.5)
Mimetidae	1	(1.0)	1	(0.1)	-	-	-	-	1	(2.0)	1	(0.3)
Total	97	(100.1)	1395	(99.9)	72	(100.2)	1025	(99.8)	50	(100.0)	372	(99.9)

Using this scheme, we examined both counts of individuals and species to calculate percentages of dominant species for each locality as a whole, and for each sampled site.

2. *Cluster Analysis.* To assess the similarities between the spider fauna among habitats at each locality we used cluster analysis to describe the “distance” between the spider faunas of each site. This gives a measure that is proportional to the β diversity among sites (Southwood 1978). To reduce the influence of unequal sampling intensities (sweep and pitfall methods) among habitats on the analysis, we ranked the abundance of each species in each habitat. The ranks were then subjected to a single linkage nearest-neighbour clustering based on a gamma distance metric (Wilkinson et al. 1992). Juvenile specimens, which cannot be identified to species, were excluded from this analysis; they constitute a small proportion (less than 8%) of the collected specimens.

3. *Guild Composition Analysis.* Spider species can be placed into functional groups called guilds which reflect habitat preferences and methods of prey capture (Post and Reichert 1977; McIver et al. 1992). We classed each species into a guild using the definitions of Post and Reichert (1977); Gertsch (1979), and McIver et al. (1992), and graphically described guild composition in each habitat based on relative abundance. Juvenile specimens were excluded from this analysis. Guild membership is strongly correlated with family membership although there are fewer guilds than families.

Collections of pitfall traps are always difficult to assess quantitatively in a meaningful way. Our emphasis has been to present presence, absence or activity data as clearly as possible with no implications of population densities. In interpreting these analyses we assume that species will vary in their tendency to be captured by the sampling methods used in this study, but that their distribution patterns among sites will be less affected by this bias.

Results

A total of 1747 spiders representing 129 species in 17 families, and 125 opiliones representing 3 species were collected from both localities during the study (Table 1). More specifically, 1395 spiders from 99 species, and 110 opiliones from 3 species were collected during summer and winter sampling at TBS. A total of 353 spiders from 49 species and 16 opiliones from one opilionid species were collected during the summer sampling at SIL. Twenty-two spider species and one opilionid species were common to both localities. At TBS, 27 spider species were captured during the winter months only (Table 1). Other specimens in 7 genera were juveniles and could not be identified to species. At both localities, most spider species were uncommon or rare (i.e., represented by fewer than 10 individuals): 68 species (70%) at

TABLE 3. The number of spider species and specimens in each family taken from the five forest upland sites sampled at SIL. Families are listed in descending order of abundance of specimens. Percentages are shown in brackets.

Family	Species	%	Specimens	%
Lycosidae	10	(20.0)	168	(47.6)
Gnaphosidae	10	(20.0)	78	(22.1)
Agelenidae	1	(2.0)	41	(11.6)
Linyphiidae	5	(10.0)	15	(4.2)
Clubionidae	3	(6.0)	13	(3.7)
Erigonidae	7	(14.0)	11	(3.1)
Salticidae	2	(4.0)	7	(2.0)
Thomisidae	4	(8.0)	6	(1.7)
Tetragnathidae	1	(2.0)	6	(1.7)
Philodromidae	2	(4.0)	3	(0.8)
Theridiidae	1	(2.0)	1	(0.3)
Amaurobiidae	1	(2.0)	1	(0.3)
Araneidae	1	(2.0)	1	(0.3)
Hahniidae	1	(2.0)	1	(0.3)
Liocraniidae	1	(2.0)	1	(0.3)
Total	0	(100.0)	353	(100.0)

TBS and 41 species (82%) at SIL. Only 2 species were common (i.e., each species accounting for over 10% of the total spider specimens) at TBS: *Agroeca ornata* Banks (13.2%) and *Pardosa xerampelina* (Keyserling) (10.9%). Most of the *A. ornata* specimens (93.0%) at TBS were taken in winter samples. Three different species were common at SIL: *Pardosa mackenziana* (Keyserling) (25.8% of all specimens), *Gnaphosa microps* Holm (11.9%), and *Agelenopsis utahana* (Chamberlin and Ivie) (11.6%).

To begin assessing taiga spider community characteristics at these two localities, we examined patterns of species dominance. The dominant spider families at TBS were Erigonidae, Linyphiidae, and Lycosidae and Gnaphosidae, while the subdominant families were Agelenidae and Amaurobiidae (Table 2). The community composition varied among seasons at TBS. Summer-dominant spider families were Erigonidae, Lycosidae, and Gnaphosidae, while winter-dominant families were Linyphiidae and Erigonidae (Table 2). Most specimens collected at TBS in summer were lycosids (53.4%), erigonids (12.9%) and hahniids (11.0%), while the winter-active specimens were commonly liocranids (46.2%), erigonids (20.7%), and linyphiids (15.3%) (Table 2). A total of 21 spider genera and 16 identifiable species were taken only in the winter months (Table 1), while 18 species in 17 genera were captured both in summer and winter. No opiliones were captured in winter.

The order of spider family dominance at SIL differed slightly from the TBS summer samples. The families Lycosidae, Gnaphosidae, and Erigonidae dominated at SIL, while the Linyphiidae, Thomisidae, and Clubionidae were subdominant (Table 3). Similar to TBS, most of the specimens collected at SIL were lycosids (47.6%; Table 3). Unlike TBS

summer samples, gnaphosids (22.1%) and agelenids (11.1%) were much more common than either erigonids (3.1%) or the hahniids (0.3%) at SIL. Dry weather during the sampling period at SIL may have reduced catches of linyphiids and erigonids due to low relative humidity.

Individual arachnid species found at each forest upland site at TBS is shown in Table 4, while Table 5 shows the same for SIL sites. In general, only two species were taken in all forest habitats sampled during the summer at TBS: the lycosids *Alopecosa aculeata* (Clerck), and *Pardosa mackenziana* (Keyserling). Only *Agroeca ornata* was taken in all habitats sampled during the winter at TBS. Up to 19 species of spiders, and one species of opilionid [*Odiellus pictus* (Wood)] were captured in only one habitat during the summer, as were 12 identifiable spider species during the winter (Table 4). However, as none of these captures in any habitat exceeded 10 individuals, it is unclear if these species are habitat specialists, or simply uncommon in our samples. Only the Alder-Tamarack ecotone (AT-EC) had fewer than 20 spider species in summer (Table 4), while both the Alder-Ridge ecotone (AR-EC) and Aspen Upland (AS-UP) sites had the highest species richness (32 species) in summer. In winter, the Jack-Pine Sand Plain (JP-SP) had the lowest species richness (8) and the AT-EC site the highest (34).

Summer species abundance and richness patterns were roughly similar at SIL (Table 5), although no direct comparisons with TBS patterns can be made because of the more limited sampling conducted at SIL. Only one species (*Pardosa mackenziana*) was taken in all five habitats, while both *Agelenopsis utahana* and *Alopecosa aculeata* was taken at four of the five sites. Except for the opilionid *Odiellus*

TABLE 4. Individual arachnid species (listed alphabetically) taken from the seven forest upland species sampled at TBS (summer and winter data shown separately). Shown are the total numbers of males, females and juveniles taken at each site. Letter codes are given in text; a (W) indicates winter data.

Species	AR-EC	AT-EC	AT-EC (W)	AS-UP	AS-UP (W)	JPR-F	JPR-O	JPR-O (W)	JPR-M	JP-SP	JP-SP (W)	Total
ARANEAE												
<i>Agelenopsis utahana</i>						1/0	4/0		0/1	2/0		7/1
<i>Agroeca ornata</i>	5/0		80/24/9	1/2	20/8	1/0	1/0	19/0	0/3		4/1/4	131/38/13
<i>Allopecora pinnata</i>	11/11		1/2	1/0	1/0							14/13
<i>Alopecosa aculeata</i>	1/2	2/0		0/4		2/4	0/6		1/13	3/0	0/1	9/29
<i>Amaurobius borealis</i>			2/2		0/1		0/1					2/5
<i>Antistea brunnea</i>		0/1										0/1
<i>Arctobius agelenoides</i>			1/0									1/0
<i>Arctosa rubicunda</i>				0/2								0/2
<i>Bathyphanes pallidus</i>				4/2	1/0	3/0	1/0					27/16
<i>Centromerus longibulbus</i>	13/14	5/0				0/1						0/1
<i>C. persolatus</i>					6/7							6/7
<i>Ceraticelus fissiceps</i>									1/0	0/1		1/1
<i>C. laetus</i>	0/1											0/1
<i>C. minutus</i>				0/1								0/1
<i>C. sp.</i>							1/0					1/0
<i>Cicurina brevis</i>					5/1/1			4/0		2/0		14/5/1
<i>C. robusta</i>			3/4	1/1	2/0					1/0		4/2
<i>Clubiona gertschi</i>			0/1	0/1								0/1
<i>C. kulezyskii</i>	0/1	0/1										0/2
<i>Coras montanus</i>			0/1			1/0	1/0		1/0			2/1
<i>Cybaeota calcarata</i>				0/1								1/1
<i>Cybaeopsis euoplus</i>	1/2	0/1	1/4/1		1/1					1/1/1		4/9/2
<i>C. tibialis</i>			2/0									2/0
<i>Dicymbium elongatum</i>	0/1	1/0						1/0				1/1
<i>Diplocentria bidentata</i>			1/0	2/0		0/1	1/3	0/1	0/3	1/1		2/0
<i>Drassodes neglectus</i>												4/8
<i>Entelecara</i> sp.						7/2						0/1
<i>Erigone atra</i>			0/1									7/2
<i>Ero canionis</i>			0/1									0/1
<i>Eularia</i> sp.				0/2						0/2		0/1
<i>Evarcha hoyi</i>												0/4
<i>Gnaphosa microps</i>												2/1
<i>G. muscorum</i>	2/0		1/0			1/0	2/0	0/1	0/1	1/0		10/1
<i>Grammoneta angusta</i>							3/1		2/0	0/1		0/1
<i>G. gigas</i>	2/1	1/0		1/0								4/1
<i>G. pictilis</i>	0/1									3/1		3/2
<i>Habrocestum pulex</i>				0/1								0/1

(Continued)

TABLE 4. (Continued).

Species	AR-EC	AT-EC	AT-EC (W)	AS-UP	AS-UP (W)	JPR-F	JPR-O	JPR-O (W)	JPR-M	JP-SP	JP-SP (W)	Total
<i>Hahnia cinerea</i>	0/1		0/1						4/0			4/2
<i>H. inornata</i>			1/0									1/0
<i>Haplodrassus eunis</i>				1/0					1/0			1/0
<i>H. signifer</i>			0/1		2/3					0/1		1/1
<i>Helophora insignis</i>											0/1	2/5
<i>Herphyllus ecclesiasticus</i>									2/1	0/3		2/1
<i>Hogna frondicola</i>							0/1					0/4
<i>Hybauchenidium cymbadentatus</i>		0/1										0/1
<i>H. gibbosum</i>			0/1									0/1
<i>H. sp.</i>					1/0							1/0
<i>Lathys pallida</i>									3/0			3/0
<i>Lepthyphantes alpinus</i>			0/1									0/1
<i>L. complicatus</i>	0/1		4/4			0/1				0/1		4/7
<i>Lepthyphantes intricatus</i>	1/3		0/4	1/2	1/2							3/11
<i>L. zebra</i>			1/2	0/1	0/2			0/1				1/6
<i>L. sp.</i>					0/1							0/1
<i>Lophomma sylvaticum</i>	0/2		1/1							1/0		1/2
<i>Macrargus multesimus</i>												1/1
<i>Meioneta simplex</i>							1/1		2/1	2/0		5/2
<i>Micaria aenea</i>		0/1					0/1		0/1	0/2		0/1
<i>M. pulicaria</i>	0/2			2/2	0/2	1/0	0/1		0/1			3/8
<i>Microneta viaria</i>												0/2
<i>Neonistea agilis</i>	1/1			10/5			40/24		15/10	0/1		66/41
<i>Neon nelli</i>								0/0/1		0/1		0/1
<i>Nerene clathrata</i>			0/1									0/1/1
<i>Oedothorax trilobatus</i>	0/1											0/1
<i>Oreonetides recurvatus</i>					1/0							1/0
<i>O. sp. nr. flavus</i>			0/1									0/1
<i>Oxyptila sincera can.</i>	0/2		0/1	0/2	0/1							0/6
<i>Pardosa hyperborea</i>	2/0	1/0				3/2	0/4		45/17	6/6		57/29
<i>P. mackenziana</i>	24/14	15/9	0/2	5/3		1/3	3/4		8/7	8/9		64/51
<i>P. moesta</i>	6/18	0/2		6/24		5/2			7/0	7/0		24/46
<i>P. xerampelina</i>	0/2			0/1		128/19						128/22
<i>Phrurotinus borealis</i>					0/1				0/1	0/1		0/3
<i>Pirata bryantae</i>						1/0	1/0					2/0
<i>P. insularis</i>	11/15	8/4				3/1						22/20
<i>P. minutus</i>				0/1		2/1	0/1		1/0			3/3
<i>P. sedentarius</i>	1/0					1/0						2/0

(Continued)

TABLE 4. (Concluded).

Species	AR-EC	AT-EC	AT-EC (W)	AS-UP	AS-UP (W)	JPR-F	JPR-O	JPR-O (W)	JPR-M	JP-SP	JP-SP (W)	Total
<i>Porrhomma</i> sp.				1/0								1/1
<i>Pocadicnemis americana</i>	4/7	0/2	0/1	2/6	0/1	3/5	10/4		6/8			25/33
<i>Robertus fuscus</i>		1/0	2/2									3/2
<i>Sciastes truncatus</i>			3/2					0/2	1/0	0/1		4/5
<i>Scotinella pugnata</i>				2/0		0/1						4/5
<i>Scotinotylus pallidus</i>						0/1						0/1
<i>Sisicus apertus</i>			10/2					0/1				10/3
<i>Sougambus bostoniensis</i>	0/1			2/0								2/1
<i>S.</i> sp.			0/1									0/1
<i>Tapinocyba minuta</i>			5/3	2/0						1/1		2/0
<i>T. simplex</i>			1/1									6/4
<i>T.</i> sp.			0/0/2									1/1
<i>Tetragnatha</i> sp.												0/0/2
<i>Theridion</i> sp.					0/0/1							0/0/1
<i>Trochosa terricola</i>			3/0	1/1	1/0	8/1	3/6	0/1/1	4/3	2/3		22/15/1
<i>Tunagyna debilis</i>	1/1					6/0	1/0					8/1
<i>Tutelina similis</i>							0/1					0/1
<i>Vermontia thoracica</i>						0/1	1/0					1/1
<i>Wabasso cacuminatus</i>	1/0											1/0
<i>Walckenaeria atroibialis</i>		1/3				0/1	1/2					2/6
<i>W. castanea</i>	0/1		17/6		4/1	0/5				1/0		22/13
<i>W. directa</i>	4/2		1/1			0/2	0/1		0/1			5/7
<i>W. exigua</i>				0/1		0/1						0/2
<i>W.</i> sp.			0/2					0/1				0/3
<i>Xysticus elegans</i>				1/0								1/0
<i>X. ellipticus</i>				2/0								2/0
<i>Zelotes frateris</i>	2/5			5/5		1/1	3/0		1/4	5/4		19/22
Total Araneae Individuals	93/113	35/25	141/80/12	50/75	53/35/2	179/56	78/61	24/7/2	98/75	42/38	9/6/5	802/571/21
Total Araneae Species	32	16	34	32	21	30	25	8	24	23	8	253
OPLIONES												
<i>Leiobunum calcar</i>	14/16			19/24			5/13		0/1	0/1		38/55
<i>L. vittatum</i>							1/1		6/3			7/4
<i>Odiellus pictis</i>	1/5											1/5
Total Opiliones Individuals	15/21			19/24			6/14		6/4	0/1		46/64
Total Opiliones Species	2			1			2		2	1		3

TABLE 5. Individual arachnid species taken from the five forest upland sites at SIL in summer. Numbers are as in Table 4. Letter codes are:as given in the text.

Species	C	LB	OP	SB	SWB	Total
ARANEAE						
<i>Agelenopsis utahana</i>	1/2	3/0	15/1	17/2		36/5
<i>Agroeca ornata</i>			0/1			0/1
<i>Alopecosa aculeata</i>		0/2	0/3	0/1	0/1	0/7
<i>Arctosa alpigena</i>		0/1		2/0	0/2	2/3
<i>A. rubicunda</i>					0/1	0/1
<i>Cybaeopsis euoplus</i>	0/1					0/1
<i>Clubiona canadensis</i>	0/1					0/1
<i>C. furcata</i>				1/0		1/0
<i>C. kulczynskii</i>	0/7		1/0	1/1	1/0	3/8
<i>Eris militaris</i>		1/0				1/0
<i>Gnaphosa brumalis</i>				0/1		0/1
<i>G. microps</i>				15/0	26/1	41/1
<i>G. muscorum</i>			1/1	1/0		2/1
<i>Grammonata angusta</i>			0/1	0/1		0/2
<i>Haplodrassus hiemalis</i>			1/0	1/0	0/1	2/1
<i>Hybauchenidium gibbosum</i>	0/2					0/2
<i>Hypselistes florens</i>	0/2					0/2
<i>Lepthyphantes turbatrix</i>	0/1					0/1
<i>Micaria aenea</i>		0/2	0/7		0/3	0/12
<i>M. constricta</i>					2/0	2/0
<i>M. pulicaria</i>			0/1			0/1
<i>Micaria tripunctata</i>				1/1		1/1
<i>Microneta viaria</i>	0/1					0/1
<i>Misumena vatia</i>	0/0/1					0/0/1
<i>Neoantistea agilis</i>		1/0				1/0
<i>Nereine radiata</i>	1/0	1/0				2/0
<i>Nuctenea patagiata</i>				1/0		1/0
<i>Pardosa fucifera</i>				0/1		0/1
<i>P. hyperborea</i>		0/1	1/5		9/17	10/23
<i>P. mackenziana</i>	0/2	0/40	4/9	0/18	7/11	11/80
<i>P. moesta</i>	0/1			0/2		0/3
<i>P. xerampelina</i>	0/1	0/5	0/11			0/17
<i>Pelecopsis mengii</i>				1/0		1/0
<i>Philodrommus cespitum</i>					1/1	1/1
<i>P. histrio</i>	0/1					0/1
<i>Phidippus borealis</i>	0/6					0/6
<i>Pirata minutus</i>				1/0		1/0
<i>Pityohypantes phrygrianus</i>	2/0	0/2	0/6			2/8
<i>Pocadicnemis americana</i>			1/1			1/1
<i>Porrhomma terrestris</i>			0/1			0/1
<i>Sisicottus montanus</i>		0/1				0/1
<i>Tetragnatha versicolor</i>	2/1		3/0			5/1
<i>Theridion petraeum</i>	0/1					0/1
<i>Trochosa terricola</i>	0/1	0/3	1/3	0/1		1/8
<i>Walckenaeria castanea</i>		0/1				0/1
<i>Xysticus chippewa</i>		0/1				0/1
<i>X. emertoni</i>	0/2	0/1				0/3
<i>X. obscurus</i>		0/1				0/1
<i>Zelotes fratis</i>	1/0	1/0	6/2	1/0		9/2
<i>Z. puritanus</i>					0/1	0/1
Total Araneae Individuals	7/33/1	7/61	34/53	43/29	46/39	137/215/1
Total Araneae Species	21	18	18	19	12	88
OPILIONES						
<i>Odiellus pictus</i>				11/4/1		11/4/1
Total Opiliones				11/4/1		11/4/1

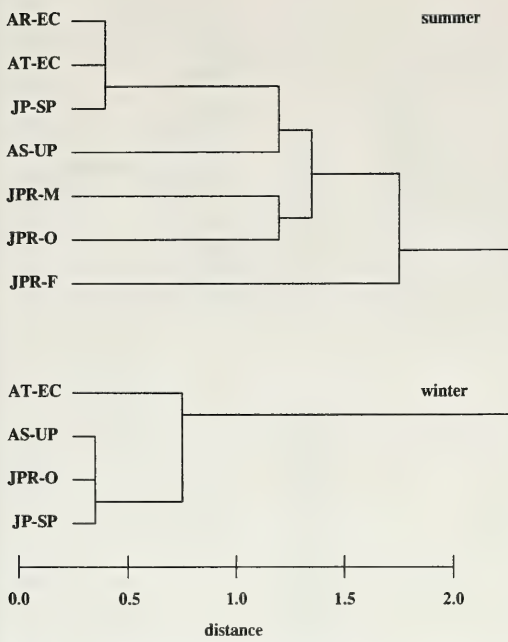


FIGURE 1. Dendrogram showing the nearest-neighbour gamma distance between the ranked species abundances at each habitat sampled at TBS in summer (top), and winter (bottom). Letter codes for the habitats are defined in text.

pictus at South Bay (SB), no species was caught in substantial numbers at only one site. Only *Pardosa hyperborea* (Thorell) was taken substantially more frequently at one site (Swan Bay: SWB) than at any other. In terms of species richness most sites were roughly equivalent at between 18 and 21 species (Table 5). Only the SWB had substantially fewer species (12).

Cluster analysis of the summer spider species distribution among habitats at TBS revealed that their spider faunas generally classed into two broad groups: the mixed deciduous-coniferous forest habitats (AR-EC, AT-EC and AS-UP), and Jack-Pine dominated habitats (JPR-M, JPR-O) (Figure 1). Interestingly, the fauna of the Jack Pine sand plain (JP-SP) was more similar to the mixed habitats, than to the other Jack Pine dominated habitats by this analysis. The Jack Pine sand plain habitat type has a relatively diverse plant species composition compared with other Jack Pine habitat types (Schaefer 1993), perhaps accounting for this result. The fauna of the freshly burned Jack Pine ridge site (JPR-F) was distinctly different from all other faunas (Figure 1). As noted above, the winter spider faunas were generally less diverse than the summer faunas, and therefore less obviously distinguishable among habitats (Figure 1). The exception was the AT-EC site, whose spider fauna was the most diverse in winter

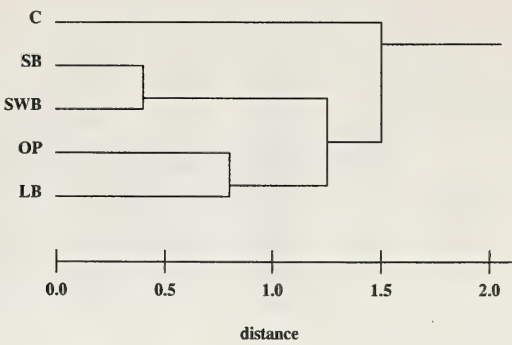


FIGURE 2. Dendrogram showing the nearest-neighbour gamma distance between the ranked species abundances at each habitat sampled at SIL in summer. Letter codes for the habitats are defined in text.

(Table 4). Relationships between spider fauna and habitat were less clear at SIL (Figure 2). The faunas of the mixed deciduous-coniferous forest habitats (C and LB) contrasted more strongly with each other than they did to those of the more coniferous-dominated sites (SB, SWB, and OP). It is possible that moderate human-caused disturbance frequency in the area of the C site may have contributed to this distinctness.

Reflecting the patterns of family dominance, the most common guilds of spiders in all habitats at TBS during the summer was the diurnal running guild (mostly lycosids), followed by the sheet-web weavers (largely erigonids and some linyphiids) (Figure 3). Other guilds were minor contributors to the spider fauna in summer with the exception of the web-line guild (mostly hahniids) in the old growth Jack-Pine (JPR-O) site. Spider guild composition among habitats was almost identical in winter, with the sheet-web weavers and nocturnal running guilds overwhelmingly dominant. At SIL, the summer fauna guild structure was broadly similar to TBS (Figure 4), with a relatively larger contribution from the the web-line guild (mostly agelenids).

Discussion

Patterns of heterogeneity in arachnid communities in Manitoba taiga upland forest habitats are broadly similar to those in European taiga forests (Niemela et al. 1996). We found substantial differences in the diversity of arachnid communities among sites and among habitats within sites in this study. Overall, in southern Manitoba taiga uplands (TBS), we collected 99 species of spiders from 15 families, while in the north (SIL) we collected 49 species from 13 families, for a total of 129 species from 17 families. We found nineteen species common to the two study regions: these are Lycosidae (8 species), Gnaphosidae (5), Erigonidae (3), and Agelenidae, Amaurobiidae, Clubionidae, Hahniidae, Linyphiidae

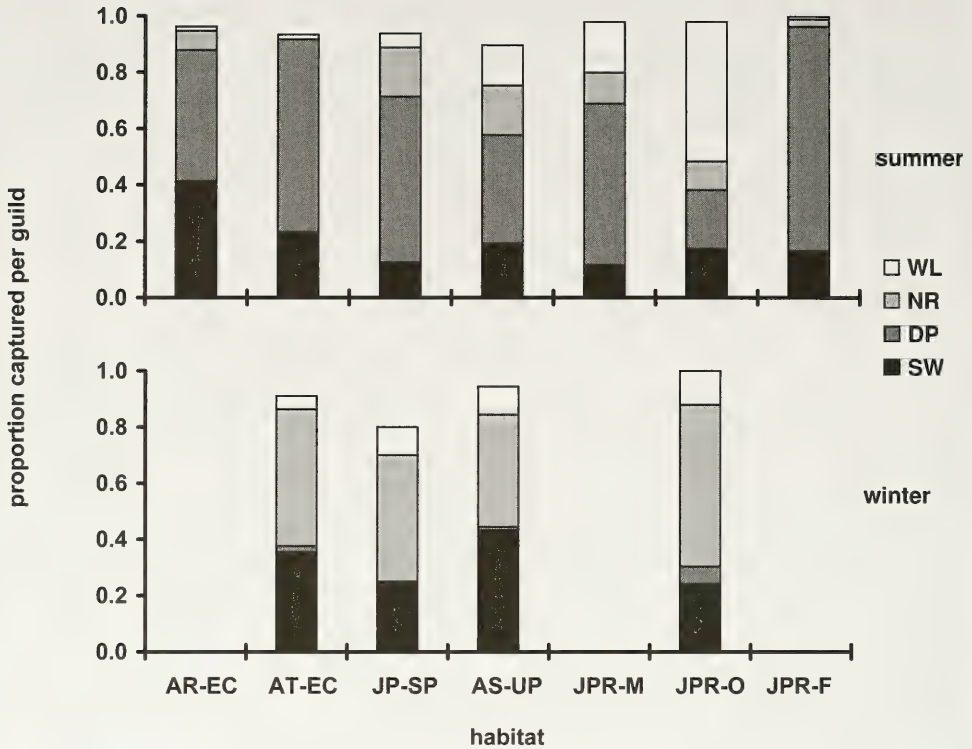


FIGURE 3. Proportion of spiders taken per guild at each of the TBS sites in summer (top) and winter (bottom). Sites are arranged in the same order as they appear in Figure 1 (top). Data are shown for the four most common guilds only. Letter codes for the sites are as in Table 4. Guilds are SW, sheet line weaver; DP, diurnal pursuit; NR, nocturnal running; and WL, web-line.

and Liocraniidae (1 species each), as well as one species of opilionid, *Odiellus pictus*.

We found the dominant species in southern Manitoba taiga to be *Agroeca ornata* and *Pardosa xerampelina*, while in the north they are *Pardosa mackenziana*, *Gnaphosa microps* and *Agelenopsis utahana*. In the bogs of southern Manitoba taiga the same two species were dominant, while in northern taiga bogs, the first two species dominated (Aitchison-Benell 1994). In contrast the dominant species of Finnish forest soils and litter were usually linyphiids, erigonids [especially *Tapinocyba pallens* (O.P.-Cambridge)], and theridiids (Huhta 1965, Palmgren 1972), and some clubionids (Palmgren 1972). Dominant species of clearcuts in Maine were *Pardosa mackenziana* and *Pardosa xerampelina* (Jennings et al. 1988), also common in open upland taiga of Manitoba. The most dominant species in Manitoba (e.g. the *Pardosa* spp.) were also collected in more open habitats. *Pardosa mackenziana* inhabits areas such as open spruce forests, mosses, grasses and herbs, (and open shoreline at SIL), while *Pardosa xerampelina* (almost exclusively in the freshly burnt jack pine at TBS, 147 of 150 individuals), especially

prefers open areas (Dondale and Redner 1990). The liocranid *Agroeca ornata*, collected during winter from alder-tamarack ecotone and aspen upland at TBS, inhabits ground litter with decaying wood of forests, mosses and lichens (Dondale and Redner 1982). The gnaphosid *Gnaphosa microps*, collected in pan traps at SIL, is commonly caught in pitfall traps and inhabits moss of birch forests and under stones (Platnick and Dondale 1992). The agelenid *Agelenopsis utahana* from SIL was frequently caught in pan traps along raised shoreline with *Picea mariana*.

The dominant families at TBS are Erigonidae, Linyphiidae, Lycosidae and Gnaphosidae, while at SIL they are Lycosidae, Gnaphosidae and Erigonidae, also dominant families in taiga of Finland (Huhta 1965; Palmgren 1972; Hippa and Mannila 1974; Palmgren and Biström 1979; Biström and Väisänen 1988; Väisänen and Biström 1990), Russia (Eskov 1981), and Siberia (Koponen and Marusik 1992). Huhta (1965) found that 96.7% of the total individuals were in the families Erigonidae, Linyphiidae and Theridiidae, with an erigonid-linyphiid predominance (Huhta 1965; Väisänen and Biström 1990). Litter-dwelling theridiids, which are usually sieved from lit-

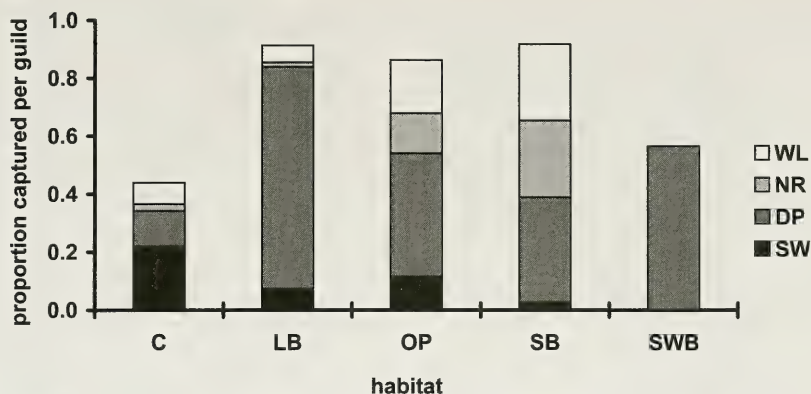


FIGURE 4. Proportion of spiders taken per guild at each of the SIL sites. Data are shown for the four most common guilds only. Letter codes for the sites are as in text; guild designations are as in Figure 2.

ter, were not collected here. In clear-cut areas Jennings et al. (1988) found that lycosids were often abundant, approximately 55% of the total catch, while Eskov (1981) collected up to 35% lycosids in meadows. In contrast, linyphiids and erigonids thrived in undisturbed, dense forest (Jennings et al. 1988; Väisänen and Biström 1990). In Manitoba taiga the lycosids predominated in open areas, and the eriogonids and linyphiids in more dense forested areas.

Finnish taiga shares these 19 species with Manitoban uplands: *Alopecosa aculeata* (Clerck), *Pardosa hyperborea* (Thorell), *Trochosa terricola* Thorell, *Pityohyphantes phrygianus* (C.L. Koch), *Erigone atra* Blackwall, *Helophora insignis* (Blackwall), *Microneta viaria* (Blackwall), *Neriene clathrata* (Sundevall), *Diplocentria bidentata* (Emerton), *Nuctenea patagiata* (Clerck), *Gnaphosa muscorum* (L. Koch), *Haplodrassus signifer* (C.L. Koch), *Micaria aenea* Thorell, *Micaria pulicaria* (Sundevall), *Zelotes frateris* Chamberlin, *Clubiona kulczynskii* Lessert, *Philodromus cespitum* (Walckenaer), *Misumena vatia* (Clerck) and *Xysticus obscurus* Collett (Huhta 1965; Palmgren 1972; Hippa and Mannila 1974; Palmgren and Bistrom 1979; Niemela et al. 1996), while Siberia shares 15 species in eleven families (Koponen and Marusik 1992). By contrast, Norwegian birch forest shares one species, *Xysticus obscurus* (Hauge 1977). In North America the state of Maine shares 36 species in twelve families (Hillburn and Jennings 1988; Jennings et al. 1988). Fifty-seven species from Manitoba were also collected in eastern Canadian taiga of northern Quebec by Koponen (1994), including 18 species of erigonids, 10 species of lycosids, 9 species of linyphiids, 6 species of gnaphosids, quite a close correlation. This contrasts sharply with the peatland fauna of southern Ontario and Quebec, where only four species are shared (*Antistea brunnea* (Emerton), *Centromerus longibulbus* (Emerton), *Callioplus euoplus* Bishop and

Crosby, and *Pardosa hyperborea*) (Dondale and Redner 1994). Taiga bogs of Manitoba share 73 species with the taiga uplands (Aitchison-Benell 1994). Thus the fauna of Manitoba is distinctly more northern in nature than that encountered in southern Ontario.

A total of 384 individuals from 49 species were collected during two winters of subnivean pitfall trapping, with 27 species taken only in the winter season. The species, *Agroeca ornata*, a common winter-active spider (Aitchison 1984; Aitchison-Benell 1994), accounted for 44.0% ($n = 169$) of the total winter catch from taiga uplands, as opposed to 91.6% of the total bog winter catch (Aitchison-Benell 1994). Of all the specimens collected of this species, 92.9% were taken during winter months. Other winter-active species were *Walckenaeria castanea* (Emerton) (7.6% of total catch; $n = 29$), *Cicurina brevis* (Emerton) (5.2%; $n = 20$), and *Sisicus apertus* (Holm) (3.4%; $n = 13$).

Our results demonstrated substantial differences in arachnid community structure between the habitat types we examined. In general, mixed deciduous-coniferous forests in Manitoba taiga had the most diverse arachnid community composition as measured by species richness, and their faunas were broadly related as measured by their guild composition. The most species-rich site at TBS was the alder-tamarack ecotone during winter, when 34 species (233 individuals) were collected. Next most species-rich sites were the alder-ridge ecotone and aspen upland (32 species each; 206 and 125 individuals respectively), followed by the recently burnt jack pine ridge (30 species; 235 individuals) (Table 4). The first three sites were undisturbed and diverse (corroborated by bog data; Aitchison-Benell 1994), while the last site was greatly disturbed and with a large influx from the lycosid guild. Again, the winter produced a diversity of species on ridges as well as in

bogs (Aitchison-Benell 1994). At SIL the camp site (the most disturbed) produced the most species (21; 41 specimens), followed by South Bay (19 species; 72 specimens) and Long Bay and Opach sites (each 18 species; 68 and 87 specimens respectively) (Table 5). Such differences in patterns of species richness, species dominance and guild composition among the habitats we sampled (especially during the summer) are consistent with observations of high among-habitat diversity (e.g., beta-diversity *sensu* Whittaker 1972) in spider communities found by Niemela et al. (1996). Our results imply that their suggestion of maintaining habitat heterogeneity at all scales to preserve local and regional diversity patterns of forest floor arachnid communities in taiga forests is a general one and applies in Canadian taiga.

Differences in sampling effort and collection methods between the northern and southern sites preclude making detailed inferences about regional diversity (e.g., gamma-diversity; Whittaker 1972) from these data. At TBS, hand collection (e.g., sweeping and beating) was impeded by a lack of vegetation in those sites recently burned. At SIL, a larger number of individuals were hand collected, including araneids. More intensive collecting (192 summer and 92 winter collection periods) was done in the south at TBS, while only 44 collection periods and no winter sampling was done at SIL.

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Ontario Goldenseal, *Hydrastis canadensis*, Populations in Relation to Habitat Size, Paths, and Woodland Edges

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Relationships between Goldenseal (*Hydrastis canadensis* L.) populations and habitat size, paths, and woodland edges were explored in order to provide information necessary for conservation planning. Habitat size was considered in the broad context of size of natural area as well as in the narrower context of size of suitable, more or less wooded habitat. Linear regression demonstrated a marginally significant negative relationship between number of stems and natural area size. A significant negative relationship was found between number of stems and habitat size. Chi-square tests, based on comparison of frequencies of Goldenseal patches with frequencies of random neighbourhood points within 5 m of paths and 10 m of woodland edges, revealed a significant association between Goldenseal and both paths and edges. Regression of population size with a disturbance factor, based on both paths and edges, revealed a significant positive effect of disturbance. These relationships suggest that Goldenseal may be adequately protected in relatively small areas, that certain kinds of disturbance may not be detrimental, and that simulation of natural disturbance could even lead to successful recovery.

Key Words: Goldenseal, *Hydrastis canadensis*, Ontario, threatened, rare, plant, population size, habitat size, paths, woodland, edges, disturbance, medicinal, recovery, conservation.

The North American perennial woodland herb, Goldenseal (*Hydrastis canadensis*), was listed as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 1991 due to historic habitat loss, few scattered populations in remnant woodlots, and potential threat from harvesting (White 1991*). In Canada this increasingly popular medicinal plant is restricted to a portion of southwestern Ontario (Sinclair and Catling 2000). An updated status report recommending threatened status is currently under review (Sinclair and Catling 1998a*). In the United States, Goldenseal is considered either critically imperiled, imperiled, rare, or uncommon in all 27 states having native populations (Robbins 1996; USFWS 1997*). In 1998, Goldenseal was added to Appendix II of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora, WWF-US 1998*). Development of a reliable conservation plan is hampered by lack of information regarding its environmental requirements (Sinclair and Catling 1998b*; USFWS 1997*; White 1991*).

A number of recent studies have suggested a beneficial effect of patchy disturbances on native woodland herbs (e.g., Hughes 1992). Sinclair and Catling (1998b*, 2000) noted circumstantial evidence for a positive relationship between disturbance and occur-

rence of Goldenseal. The evidence included proximity to recreational paths, woodlot edges, and previous flooded zones, evidence of past logging, presence in thickets and successional forests, and occurrence on riverbanks, constructed dykes, and logging roads. In addition, a preliminary analysis indicated that population size (number of stems) decreased with increasing woodlot size. This suggested that Goldenseal may not require extensive habitat and may even benefit from habitat fragmentation (Sinclair and Catling 1998b*). Here we provide quantification and evaluation of that evidence.

Methods

Data for twenty locations with populations of Goldenseal in southwestern Ontario used in this study are available from COSEWIC (see Sinclair and Catling 1998a*, 1998b*, 2000). Site numbers in Table 1 correspond to these locations. Sites are defined as occurrences at least 0.5 km distant from each other. Search method is not considered a factor biasing likelihood of Goldenseal occurrence near paths and edges. Habitats in this study as well as hundreds of potential habitats in southwestern Ontario have been surveyed systematically by the authors and many other field botanists and these surveys have not been concentrated on paths and edges.

Relationship with habitat and natural area sizes

"Habitats" were defined as more or less continuous wooded situations within which site conditions did not appear to be restrictive to development of

*See Documents Cited section.

TABLE 1. Site numbers, natural area sizes (ha), habitat sizes (km²), number of Goldenseal stems (not necessarily individual plants), number of Goldenseal patches (G points), number of neighbourhood points (N points), Chi-square for paths, Chi-square for edges, and disturbance values for 20 sites in southwestern Ontario.

Site	Habitat Size (km ²)	Natural Area Size (ha)	Number of Stems	G Points	N Points	Path G Points	Path N Points	Path Chi-sq.	Edge G Points	Edge N Points	Edge Chi-sq.	D value
1A	0.062	10.1	1153	8	43	4	10	2.689	0	6	1.120	37
1B	0.017	10.1	768	11	22	0	0	0	11	22	0	100
2	0.131	13.5	106	1	19	0	8	0.420	0	3	0.160	58
3	0.254	29.1	4400	9	90	5	16	7.225	0	0	0	18
4	0.146	11.0	45	1	8	0	0	0	0	0	0	0
5	0.121	75.1	1980	1	25	1	6	2.407	0	0	0	24
6	0.452	48.8	2597	9	55	2	3	5.339	5	7	12.538	18
7	0.289	59.2	455	3	40	0	9	0	0	3	11.207	31
8	0.059	7.9	283	5	40	3	6	7.557	4	10	6.050	40
9	0.316	35.9	165	2	42	0	0	0	14	42	0	100
10	0.026	2.7	640	6	33	0	0	0	3	7	2.403	21
11	1.175	253.6	203	3	34	0	0	0	0	5	0.450	15
12	1.175	253.6	45	1	15	0	0	0	1	5	1.360	33
13	1.150	253.6	261	1	20	0	0	0	0	0	0	0
14	1.150	253.6	10	1	15	0	0	0	0	0	0	0
15	0.300	52.1	188	2	28	2	6	5.944	0	0	0	21
16	0.071	457.4	440	3	49	3	10	9.600	3	9	11.207	38
17	0.363	457.4	37	2	24	0	0	0	0	0	0	0
18	0.022	199.6	241	1	25	1	6	2.407	1	3	6.453	36
20	0.115	90.1	648	5	11	3	2	4.900	5	7	1.012	82

Goldenseal. Our concept of continuity admitted small gravel roads but not major roads or highways, nor major rivers over 10 m wide. For example, an abrupt change in habitat such as a steep slope with dry oak forest was considered a limit to habitat. The remarkable variability of Goldenseal habitats (Sinclair and Catling 1998b*) was taken into account. "Natural areas" were broadly defined as more or less wooded areas, including those with major changes in plant associations, and were bounded by roads, open fields, agricultural land, and/or extensive water bodies. Relatively larger natural areas may provide more interaction opportunities relating to pollination and dispersal. Both habitats and natural areas were delineated and scanned on aerial photographs using information from the photos and field reconnaissance.

Linear regression was used to determine the relationship of habitat and natural area sizes to the size of Goldenseal populations with respect to both number of stems and number of patches (at least 5 m apart) at a location. Number of stems was log-transformed in order to meet the assumptions of analysis of variance. An F-ratio from analysis of variance was used to determine significance of the fit of the data to the regression model and an R-squared from correlation provided an indication of variability explained.

Relationship with paths and edges

For patches of Goldenseal (one or more plants 5 m from any other Goldenseal plant) it was noted whether the approximate central point of the patch was within 5 m of a path (i.e., a track more than 1 m wide with compacted bare soil) or 10 m of a wood-

land edge beyond which an extensive open (non-treed) area existed. The 10 m limit is well within the < 20 m for floristic features related to edges reported by Burke and Nol (1998).

Transects, with points every 20 m, were randomly set out in the neighbourhood (within 50 m) of Goldenseal patches to obtain a random sample of neighbourhood points with frequency data on proximity to paths and edges. Whether or not a transect point was within 5 m of a path or 10 m of an edge was noted. Frequencies of occurrences near paths and edges for the 638 neighbourhood points were compared with observed frequencies for 75 Goldenseal points. Expected frequencies of Goldenseal points near paths and edges for each population were calculated for each site based on the percentage of neighbourhood points near paths and edges. A Chi-square test then provided a significance value for frequency of Goldenseal points near paths and edges at each site.

In order to take variations in population size at different sites into account, the percent neighbourhood points near paths and edges was added to obtain a disturbance value for each site. Linear regression was then used to evaluate the relationship between disturbance and population size with respect to number of stems. Disturbance values and number of stems were log-transformed in order to meet the assumptions of analysis of variance.

Results and Discussion

Relationship with habitat and natural area sizes

There was a marginally significant decrease in

number of Goldenseal stems with increasing natural area size (Table 1; $P = 0.059$, $R^2 = 18.36\%$) as suggested in a preliminary analysis (Sinclair and Catling 1998b*). The relationship of natural area size with number of patches was not significant (Table 1; $P = 0.064$, $R^2 = 17.78\%$). There was a significant negative relationship between habitat size and number of stems ($P = 0.040$, $R^2 = 21.34\%$). Conversely, there was no significant relationship between habitat size and number of patches ($P = 0.126$, $R^2 = 12.51\%$). Removal of the largest and possibly less well explored sites failed to provide an indication of a significant relationship between habitat size and number of stems ($P = 0.873$, $R^2 = 0.19\%$) nor between habitat and number of patches ($P = 0.868$, $R^2 = 0.20\%$). Thus, Goldenseal tends to have relatively larger populations in relatively smaller areas. Since none of the sites have been substantially reduced in size over the past few decades we believe these data provide a reliable suggestion of minimal area effects. To the extent that small habitats may be more disturbed due to relatively increased edge effects, the data suggest that Goldenseal may be promoted by disturbance. However, edge effects on plants may not be more pronounced in small woodlots (Burke and Nol 1998). Regardless, a beneficial effect of large natural areas or habitats is not supported and the results are contrary to expectation for a species assigned a coefficient of conservatism of 10 (Oldham et al. 1995).

Relationship with paths and edges

There were no expected or observed Goldenseal points near paths for 11 sites. For the remaining nine there was a significant association with paths at six sites and a significant association with paths overall (Table 1; $P < 0.0005$). For seven of 13 sites, with expected frequency exceeding zero, Goldenseal occurrence near edges was greater than expected, and in four of these sites it was significantly greater. Overall, there was also a significantly greater association of Goldenseal points with edges ($P < 0.0005$). Although we have strived for an objective and statistically appropriate consideration of the question of effect of disturbance, an association would be a compelling conclusion with seven of the 20 known sites having Goldenseal plants within 10 cm of the compacted and bare portion of paths and sometimes even in the middle of the path.

Of the total 75 Goldenseal points at all sites, 24 were near paths and 47 were near edges (Table 1). Significantly increased frequency near paths ($P = 0.0006$) and edges ($P < 0.0005$) with regard to expectation from neighbourhood points suggest a beneficial effect of both. Furthermore, there was a significant positive relationship between disturbance value (paths and edges) and population size ($P = 0.020$, $R^2 = 26.45\%$). The strong indications of a positive relationship of Goldenseal with paths and

edges is assumed to be a consequence of associated disturbance to soil and/or canopy, but the effect may also be indirect and mediated by dispersal, pollination, or other phenomena.

Conclusion

Considering that Goldenseal is not significantly associated with extensive habitats or large natural areas, and is significantly associated with paths and edges, it appears that this threatened species may benefit from disturbances in deciduous woodland. Natural disturbances no longer prevalent on the landscape such as severe flooding of bottomland forests, fire, and faunal impacts (Sinclair and Catling 2000) may have promoted spread and colonization. For example, Passenger Pigeons (*Ectopistes migratorius* L.), Black Bears (*Ursus americanus* Pallas), and various pleistocene mammals (Kurtén and Anderson 1980) may have opened canopies, caused soil disturbance, provided nutrients, and contributed to dispersal and colonization. Research relating to recovery plans should take these possibilities into account.

The relationship of Goldenseal with habitat and natural area size suggests that Goldenseal may be adequately protected in relatively small areas supporting the view that small areas are worthy of serious consideration for species conservation (e.g., Higgs and Usher 1980; Järvinen 1982; Reznicek 1987). Reznicek (1987) explains the basis for this in depth and with comparison to animals, noting long lifespan and seedbank, inbreeding capability, fit in small areas, and use of a single habitat that may however be prone to change (Collins et al. 1985). The potentially beneficial effects of disturbance on woodland plants are less well recognized, although native species diversity may be higher in disturbed woodlands (e.g., Levenson 1981; Ranney et al. 1981) and cover of woodland herbs generally increases (e.g., Moore and Vankat 1986). In addition, a few recent studies of common woodland herbs have indicated a beneficial effect (e.g., Hughes 1992). The positive relationship between Goldenseal and disturbance suggests that simulation of natural disturbance could contribute to successful recovery. Although these results do not prove that disturbance promotes Goldenseal, they do call to question the notion that lack of disturbance is desirable, and they may also alert managers of woodlots that certain woodland herbs, such as Yellow Dog's-Tooth Violet (*Erythronium americanum*, see Hughes 1992), as well as some rare woodland herbs, including Goldenseal, may benefit from certain kinds of disturbance.

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Incidental Grizzly Bear, *Ursus arctos*, Sightings during Autumn Mountain Goat, *Oreamnos americanus*, Surveys in Westcentral British Columbia

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Demarchi, M. W., S. R. Johnson, and G. F. Searing. 2000. Incidental Grizzly Bear, *Ursus arctos*, sightings during autumn Mountain Goat, *Oreamnos americanus*, surveys in westcentral British Columbia. *Canadian Field-Naturalist* 114(4): 656–660.

While conducting surveys for Mountain Goats (*Oreamnos americanus*) in seven mountain blocks covering 3019 km² in westcentral British Columbia during autumn 1996, 57 Grizzly Bears (*Ursus arctos*) were observed in 34 groups consisting of 1–4 individuals. Grizzly Bears were observed at alpine and high subalpine elevations. It was likely that many of those bears did not forage on runs of spawning salmon (*Oncorhynchus* spp.) in the valley bottoms, thereby further demonstrating the value of higher-elevation habitats for some “coastal” Grizzly Bears during autumn.

Key Words: Grizzly Bear, *Ursus arctos*, survey, habitat, British Columbia.

The Grizzly Bear (*Ursus arctos*) is an integral component of many terrestrial ecosystems in British Columbia. Because of their vulnerability to habitat loss and excessive mortality, the Grizzly Bear is currently on the British Columbia Ministry of Environment Blue List of sensitive/vulnerable species, identifying it as a species at risk. A notoriously difficult species to inventory (Miller et al. 1997), empirical data on the abundance of Grizzly Bears in most of British Columbia are limited. Despite this, managers charged with the task of integrating industrial and commercial developments with Grizzly Bear conservation usually require, at a minimum, information on seasonal habitat-use patterns of Grizzly Bears.

Grizzly Bears exhibit great niche plasticity and extensive mobility. Home range size varies with age, sex, geographic location, and season (e.g., Ballard et al. 1993; MacHutchon et al. 1993; Waller and Mace 1997). Grizzly Bears consume large quantities of high-quality food to meet daily energy requirements; especially during late summer and autumn when they build fat reserves for the denning period. The distribution of Grizzly Bears is often related to food supply and densities are often highest in areas where food is abundant (Miller et al. 1997). Relatively high densities have been recorded along streams during salmon (*Oncorhynchus* spp.) runs, on subalpine slopes when berries are abundant, and at garbage dumps (Knight and Eberhardt 1985; LaFranc et al. 1987; Miller et al. 1997).

“Coastal” Grizzly Bears forage extensively on summer and autumn spawning runs of salmon (MacHutchon et al. 1993). However, the assumption that, where available, all Grizzly Bears necessarily consume spawning salmon is probably invalid

(Schoen et al. 1986). For Grizzly Bear habitat mapping, adopting that assumption could erroneously under-rate habitats without spawning salmon (e.g., alpine and subalpine areas), but with other suitable forage items instead. For example, in rating the habitat potential for Grizzly Bears in watersheds of the central coast region of British Columbia, Jeo et al. (1999*) considered only the presence of estuaries, riparian areas, old-growth forests (i.e., stands of trees > 30–37.5 m tall and > 200–250 years old, depending on species), and the abundance of spawning salmon. Salmon are an important source of pre-denning nutrition for many bears (e.g., MacHutchon et al. 1993), but the degree to which this applies to all Grizzly Bears in a population is unclear — especially when an abundance of alternate forage items, such as vegetation (e.g., herbage, berries) or marmots (*Marmota* spp.), exists. Conversely, given the presence of spawning, anadromous salmon at locations as far into the interior of British Columbia as Valemount (near Alberta), it is fallacious to assume that only “coastal” Grizzly Bears have access to salmon. The first objective of this article is to report on a notable number of Grizzly Bears that were observed at alpine and subalpine elevations at a time of year when salmon were spawning in the creeks and rivers below. The second is to present information suggesting that, as in Alaska (Schoen et al. 1986), “coastal” Grizzly Bears in westcentral British Columbia do not necessarily forage on salmon.

Study Area

Surveys were flown in the Nass Ranges and Kitimat Ranges ecosections within the Coast and Mountains Ecoprovince (Demarchi et al. 1990)

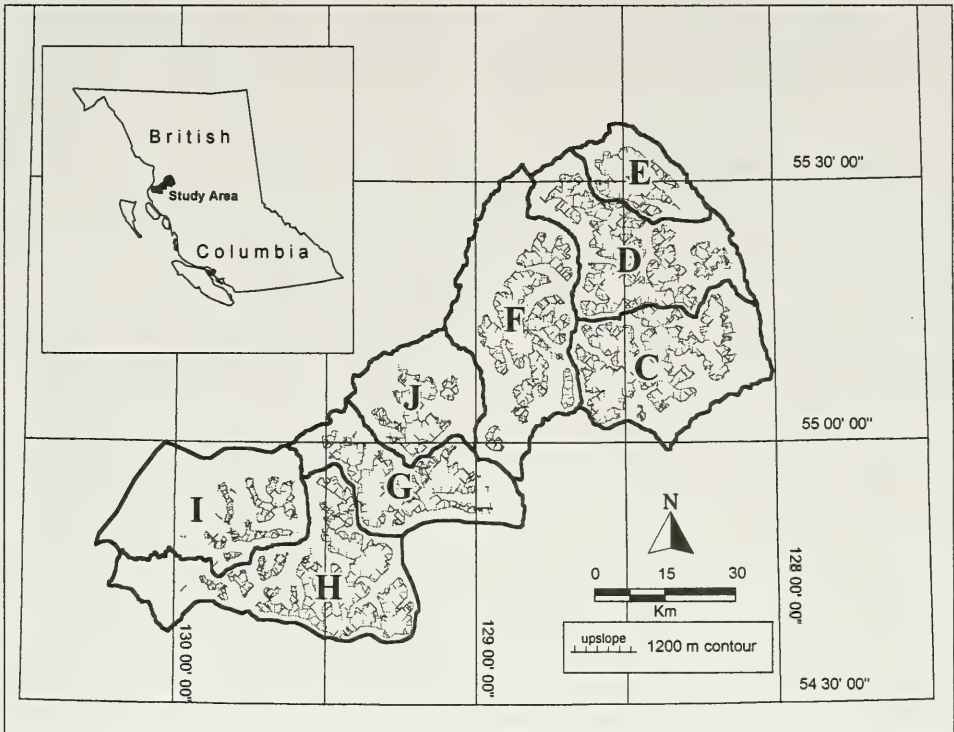


FIGURE 1. Mountain Goat survey blocks as inventoried during autumn 1996. The 1200-m contour approximates treeline.

(Figure 1). Eight survey blocks were delineated for inventory and management purposes by the authors and the provincial government. Elevations in these rugged mountains range between 0–2000 m in the west and between 200–2200 m in the east. The Nass and Cranberry rivers flow along parts of the study area’s northern and eastern boundary, and inlets of the Pacific Ocean border it to the west. Salmon spawn in many of the rivers and creeks below 600 m elevation throughout the study area, with some of the largest runs occurring in the Cranberry River. Spawning activity occurs throughout much of the year, but is greatest during July through September. Extending from the coast toward the interior of the province, the study area has climatic and vegetational similarities to both coastal and continental areas, but coastal effects are dominant (Cannings and Cannings 1996).

According to the biogeoclimatic ecosystem classification system (BEC), the study area is dominated by the Alpine Tundra (AT) biogeoclimatic zone, with lesser amounts of the Mountain Hemlock (MH), Coastal Western Hemlock (CWH), and Englemann Spruce Subalpine Fir (ESSF) biogeoclimatic zones (Banner et al. 1993). Depending on local climate and topography, the CWH zone ranges

between 0–1000 m, the MH zone occurs at elevations between 550–1600 m, the ESSF zone occurs between 900–1500 m, and the AT zone occurs at elevations above 1200–1600 m (Banner et al. 1993). Local forests are dominated by various mixtures of Western Hemlock (*Tsuga heterophylla*), Mountain Hemlock (*Tsuga mertensiana*), Western Redcedar (*Thuja plicata*), Roche Spruce (*Picea englemannii* x *glauca*), and Subalpine Fir (*Abies lasiocarpa*). Large conifers are absent from the AT zone, but conifers do occur in a krummholz (stunted) form at the lower reaches of this zone. Locally, clear-cutting of forests is the primary industry. Although the majority of watersheds in the area were undeveloped in 1996, logging is occurring in an increasing number of watersheds throughout the study area. Our observations also indicate that local human activities have increased considerably in recent years, due to the commercial harvest of wild mushrooms in low-elevation forests during late summer and autumn.

Methods

Between 7 September and 7 October 1996, aerial surveys for Mountain Goats (*Oreamnos americanus*) were conducted by three observers and a pilot in a Bell 206 Jet-Ranger helicopter (Demarchi et al.

2000). Survey effort was focused on, but not limited to, alpine and subalpine elevations. Sightings of Grizzly Bears and other wildlife were recorded as incidental records. The distance to the mountainside and the ground speed varied with topography, but generally, the helicopter was < 150 m from the mountain and ground speed was < 70 km/h. In most areas, a single pass along the perimeter of a mountain block was sufficient to scan the area thoroughly above treeline. In some areas, especially near the coast where Mountain Goats were commonly observed in forested areas, three or four passes were made across some mountain sides in order to ensure thorough coverage. Average search intensity (calculated, exclusive of topographic effects, as the total survey time (3678 min) divided by the sum of the area above the lowest Mountain Goat sighting in each block (3019 km²) was 1.2 min · km⁻².

The sex and age class of Grizzly Bears was recorded when possible. A hand-held GPS unit (Magellan ProMARK X) logged the time and position of the helicopter, and an elevation for each sighting was estimated from the GPS or the helicopter's altimeter. During the survey, all observations were plotted on 1:50 000 NTS maps to reduce the probability of recounting animals.

While biogeoclimatic zones represent areas of similar climate, vegetation, and site conditions occurring within ecosections, broad ecosystem units (BEUs) (Erwin et al. 1997) represent permanent areas of landscape that are represented by distinctive plant communities, e.g., subalpine meadows, or by physical structures, e.g., lakes, rock outcrops, that are meaningful to large species of wildlife. Both types of information were obtained for each bear sighting from digital coverages obtained from the provincial government.

Results

Thirty-four sightings of 57 Grizzly Bears were made during aerial surveys for mountain goats in an area of ~3019 km² (Demarchi et al. 1997*; Johnson et al. 1997*). Nine sightings (25%) were of adult females with cubs, i.e., 28 of the 57 (49%) Grizzly Bears recorded were in family groups. Two females each had two cubs-of-the-year (COY), and seven other females had yearling or two-year-old cubs. Of these seven, two had one cub, two had two cubs, and three had three cubs. The mean (± SD) size of all nine litters was 2.11 (± 0.78), and 2.14 (± 0.90) for the seven older litters. No adult males were positively identified, but of the 25 sightings of 29 unclassified adults and subadults, some were likely males.

Virtually all sightings of Grizzly Bears (33 of 34; 97%) were recorded in survey blocks in the eastern part of the study area (i.e., blocks C, D, E, and F), and all sightings were in the Nass Ranges Ecosection (Demarchi et al. 1990). Only one Grizzly Bear was seen west of the Tseax and Cedar river valleys; that sighting was on the far east side of block G. No Grizzly Bears were sighted in blocks H or I. That may have been a result of reduced sightability and/or an absence of animals due to a reduced abundance of open alpine and subalpine areas in those blocks. The mean (± SD) elevation of the 34 sightings was 1465 m (± 147 m), and the mean (± SD) elevation of the nine sow-cub groups was 1467 m (± 119 m). Block J was not surveyed.

The distribution of Grizzly Bears by BEU and BEC is indicated in Table 1. According to the BEU habitat classification, most bears (54%) were observed in BEU polygons that contained habitat classified as avalanche track (AV). The next greatest proportion (33%) was located in polygons contain-

TABLE 1. Numbers of Grizzly Bears sighted by biogeoclimatic zones (BEC) and broad ecosystem units (BEU)^a in west-central British Columbia, September-October 1996. Secondary BEU values reflect the fact that some BEU polygons contain more than one BEU type.

BEC ^b	BEU ^c (primary)	BEU (secondary)	Total	Adult Male	Adult Female	Sub- adult	Cub of the Year	Unclas- sified
AT	AH	AM	1					1
AT	AU	AM	19		3	4	2	10
AT	AU	GL	1					1
AT	AU	-	1					1
ESSF	EW	-	2					2
ESSF	EW	AV	13		2	6		5
ESSF	EW	EW	1					1
MH	AV	-	3		1		2	
MH	MF	SM	1					1
MH	MF	AV	15		3	5		7

^afrom Erwin et al. 1997

^bAT Alpine Tundra; ESSF Engelmann Spruce-Subalpine Fir; MH Mountain Hemlock

^cAH Alpine Heath; AM Alpine Meadow; AU Alpine Unvegetated; AV Avalanche Track; EW Subalpine Fir-Mountain Hemlock, Wet Forested; GL Glacier; MF Mountain Hemlock-Amabilis Fir; SM Subalpine Meadow

ing habitat classified as alpine meadow (AM). Thirty-nine percent were located in the AT zone, 33% were in the MH zone, and the remainder were in the ESSF zone (Table 1).

Discussion

The low density at which Grizzly Bears typically occur, their secretive nature, and their affinity for forested habitats combine to make them difficult to inventory in a rigorous manner. Although our method was not a standard inventory protocol for this species, we believe that sighting 57 Grizzly Bears during autumn Mountain Goat surveys is noteworthy. First, this underscores the importance of collecting information incidentally for one species of wildlife during formalized surveys for another. In the past, few authors documented such incidental information in standard inventory reports of wildlife in or near our study area. However, as the awareness about biodiversity has increased, more of this information is being routinely presented. Second, and more important, the substantial number of bears observed in habitats away from salmon-bearing streams at a time of year when salmon are abundant in nearby rivers and creeks provides further evidence that Grizzly Bears in coastal areas do not necessarily consume salmon during the fall. The common, though not universal, assumption that "coastal" Grizzly Bears necessarily forage on salmon is probably a result of at least several factors. First, scientists studying of "coastal" Grizzly Bears are likely to capture bears very close to salmon-bearing streams where salmon comprise a substantial part of the diet of such bears. For example, while MacHutchon et al. (1993) attempted to capture Grizzly Bears across a wide range of elevations, most bears in that study were trapped below 200 m ASL and none were trapped at alpine or subalpine locations. Second, traditional concentrations of Grizzly Bears at salmon-fishing sites are well known (e.g., Brooks River in Katmai National Park, Alaska; Olson et al. 1997). Third, the high nutrient and energy content of salmon makes it likely that many Grizzly Bears would seek this food source.

Our methodology does not permit us to conclude why Grizzly Bears occurred at higher elevations when salmon were spawning in the valleys. It is possible that: (1) valley bottom habitats were fully occupied by other bears resulting in competitive exclusion, (2) extensive human activities associated with commercial mushroom picking in the valley bottoms displaced bears to higher elevations, (3) higher-elevation habitats contained ample food resources to sustain Grizzly Bears in the fall, (4) some or all bears regularly moved between salmon-bearing streams and upper elevations, or (5) a combination of these factors was operating. Radio-telemetry data over two complete autumn seasons from three adult Grizzly Bears (two males, one female) tagged at higher eleva-

tions support the first three hypotheses, as only one bear (a male) was located (once) near a salmon-bearing stream in the fall (Demarchi and Johnson 2000*). Those data and the incidental sightings in 1996 support the findings of other researchers who have determined that some Grizzly Bears, including "coastal" ones, are able to build sufficient pre-denning fat reserves by foraging solely in higher-elevation habitats. Schoen et al. (1986) and Schoen et al. (1994) reported that >85% of Grizzly Bears on Admiralty Island in southeast Alaska were associated with anadromous fish streams in late summer, but some females and subadults remained year-round at higher elevations where salmon were unavailable. McLellan (1989) found that a proportion of the Grizzly Bears in southeastern British Columbia and northwestern Montana lived in the mountains adjacent to the Flathead Valley and rarely, if ever, descended to the valley floor. While no Grizzly Bears in the Flathead Valley forage on fish (McLellan and Hovey 1995), there are considerable similarities between vegetation communities of higher-elevation biogeoclimatic zones at coastal and interior locations (Banner et al. 1993; Braumandl and Curran 1992). Thus, many of the higher-elevation, coastal areas of British Columbia are probably capable of meeting the pre-denning forage needs of Grizzly Bears. Remote, high-elevation areas may also serve as a refuge for bears temporarily displaced from valley bottoms by humans or other bears. Therefore, in the absence of local habitat suitability information demonstrating otherwise, the potential value of high-elevation habitats distant from salmon-bearing waters should not be discounted for use by Grizzly Bears during late summer or autumn simply because salmon are available in the valleys below. Furthermore, if the recent trend of declining salmon stocks continues in British Columbia, alpine and subalpine habitats may take on an increasingly important role in the conservation of Grizzly Bears in the western reaches of the province.

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Calf Production and Overwinter Survival Estimates for Peary Caribou, *Rangifer tarandus pearyi*, on Banks Island, Northwest Territories

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In response to declining numbers of Peary Caribou (*Rangifer tarandus pearyi*) on Banks Island, sex and age classification surveys were conducted systematically from 1993–1999. Previous surveys (1982–1991) had been conducted sporadically. We compiled all data to estimate calf production (ratio of calves per 100 \geq 2 year-old females) and overwinter survival. Calf production, estimated for 11 years, ranged from 24.0 to 75.6 and was \geq 50.0 in eight years. Overwinter survival, estimated for seven years, ranged from 23–86% and was \geq 50% in four years. We partitioned classification data into five different circannual periods: calving (May and June; $n=5$), summer (July and August; $n=8$), fall/rut (September through 10 November; $n=5$), winter (11 November through March; $n=8$), and pre-calving (April; $n=3$). A Kruskal-Wallis analysis indicated year effects ($P=0.06$) on the ratio of calves per 100 \geq 2 year-old females; ratios were higher during 1995, 1996, and 1999. There was no relationship between reduced calf production or overwinter survival and increased snow depth or hardness. The drop in number of Banks Island Caribou (\geq 1 year-old) from 709 (SE 128) in 1994 to 436 (SE 71) in 1998 has happened despite high calf production, high overwinter survival of calves, and less severe winter snow conditions.

Key Words: Peary Caribou, *Rangifer tarandus pearyi*, calf production, calf survival, high arctic, Banks Island, Northwest Territories.

Peary Caribou reside in the Canadian High Arctic and were designated as an endangered subspecies by COSEWIC in 1991. Over the past 20 years, Peary Caribou numbers have decreased. Severe winter weather has been associated with die-offs throughout the High Arctic and is believed to be the major cause of this decline (Parker et al. 1975; Gunn 1992). Unfortunately, over most of the Peary Caribou range systematic population surveys are lacking and systematic estimates of calf production and overwinter survival of calves are absent. Banks Island provides one notable exception where ungulate populations have been systematically monitored by the Department of Resources, Wildlife, and Economic Development (DRWED), Government of the Northwest Territories since 1982 (Nagy et al. 1996).

From 1982 to 1998, eight islandwide population surveys were conducted during summer after calving using strip transect techniques and the Jolly method to estimate population size (Jolly 1969; Norton-Griffiths 1978). Peary Caribou numbers decreased from 6970 (SE 1133) to 436 (SE 71) non-calves (Nagy et al. 1996; J. Nagy and M. Branigan unpublished data, Figure 1). Documenting declining numbers is one thing, but evaluating the cause of the decline requires additional information. Unfortunately, sex and age classification surveys, useful for assessing calf production and overwinter survival, were conducted sporadically between 1982 and 1991, and were often done opportunistically with other ground-based field operations during winter when travel was easiest.

Most of the decline in Caribou numbers appeared to have occurred by 1991 when the population was estimated at 897 non-calves (Figure 1), and an annual quota of 30 males, was implemented for the community of Sachs Harbour. Caribou are an important traditional country food for residents of Sachs Harbour. In response to local concerns about low Caribou numbers, aerial classification surveys to assess calf production and overwinter survival were initiated in summer 1992. Another population survey was conducted; the estimate was 1005 non-calves (Nagy et al. 1996, Figure 1). The annual quota was reevaluated at the request of the Sachs Harbour Hunters and Trappers Committee and increased to 36 male caribou, allowing for one Caribou per household. In 1993, annual summer (July) aerial classification surveys were integrated into a five-year research program which also included ground-based classification surveys of 6–21 days in length conducted in June, July, August, November, February, and April. This program continued from June 1993 to July 1998; subsequent summer classification surveys of Peary Caribou have been continued.

In this paper we: (1) compile and review all available historic data from sex and age classification surveys on Banks Island, (2) document the first estimates, based upon systematic surveys, of annual calf production and overwinter survival of Peary Caribou, and (3) discuss whether estimates of calf production and/or overwinter survival support the hypothesis that severe winter weather was the main factor in population decline.

Study Area

Banks Island is the westernmost island in the Canadian Arctic Archipelago and covers approximately 70 000 km² (Figure 2). The climate is Arctic Maritime along coastal areas where weather stations are situated, tending toward Arctic Desert inland (Zoltai et al. 1980*). Winters are long, with mean monthly temperatures below 0°C from September through May, and cold, with mean minimum daily temperatures of -30 to -40°C from December to March. Summers are short and cool; mean maximum daily temperatures of 5 to 10°C from June through August. There is little precipitation; annual mean 9 cm (Zoltai et al. 1980*). Sachs Harbour (population 125) is the only permanent settlement. Zoltai et al. (1980*) provided a general overview of the geology and glacial history of Banks Island.

Habitat descriptions were adapted from Kevan (1974), Wilkinson et al. (1976), and Ferguson (1991). There are four major terrestrial habitats: (1) wet sedge meadow (WSM), (2) upland barren (UB), (3) hummock tundra (HT), and (4) stony barren (SB). WSM are generally level hydric and hygric lowlands characterized by Water Sedge (*Carex aquatilis*), Cotton Sedge (*Eriophorum scheuchzeri*), and Tundra Grass (*Dupontia fisheri*). UB are well drained sites found on the upper and middle parts of slopes. Vegetation is dominated by Mountain Avens (*Dryas integrifolia*) and Arctic Willow (*Salix arctica*). HT is found on moderately steep slopes and is characterized by individual hummocks which are vegetated primarily by dwarf shrubs including Mountain Avens, Arctic Willow, and Arctic Heather (*Cassiope tetragona*). SB have a coarse gravelly substrate and are sparsely vegetated. This habitat is found on wind blown areas, ridges, and gravel and sand bars. A more detailed description of the flora of Banks Island can be found in Wilkinson et al. (1976), Porsild and Cody (1980), and Zoltai et al. (1980*).

Muskoxen (*Ovibos moschatus*) and Peary Caribou are the dominant resident herbivores; population estimates from 1998 were 45 833 (SE 1938) and 436 (SE 71) ≥ 1 year-old animals of each species respectively (J. Nagy and M. Branigan unpublished data). Other resident herbivores include Arctic Hares (*Lepus arcticus*), Ptarmigan (*Lagopus lagopus*, *L. mutus*), Collared (*Dicrostonyx torquatus*) and Brown lemmings (*Lemmus sibiricus*). During summer there is a substantial population of nesting Snow Geese (*Chen caerulescens*), estimated at 439 000 \pm 51 000 (95% CI) in 1995 (Samelius and Alisauskas 1998*). The major resident predators are Arctic Wolves (*Canis lupus arctos*), Polar Bears (*Ursus maritimus*), and Arctic Foxes (*Alopex lagopus*).

Methods

Types of Classification Surveys

Ground-based classification surveys were conducted in November 1982, October 1990, September and November 1991, and March 1993; raw data for a survey conducted in November, 1983 were unavailable. One to four-day round trips were conducted by DRWED personnel and local guides on snowmachines from Sachs Harbour into the traditional wintering grounds north and northeast of the community (Figure 2). When Caribou were located, observers positioned themselves so that Caribou could be observed either with binoculars (7 \times 24) or a spotting scope (15-45 \times). Caribou were classified into calves, yearlings, adult females (≥ 2 years old), and adult males (≥ 2 years old). Whenever possible yearlings and calves were classified as male or female, following Bergerud (1961).

In June and August, 1992 and May and June, 1993 classification surveys were flown with a Bell 206B helicopter. Caribou were spotted from the air and the survey crew, generally an observer and a recorder, was positioned on the ground by the helicopter. To minimize disturbance and get the best view of animals possible, the helicopter landed 0.5-1.5 km downwind and preferably behind a ridge or hill so as not to be within the animals' direct line of sight. The survey crew then walked to a position where the animals could be classified with a spotting scope into the four previously described sex and age categories. In all but the June 1992 survey, an initial reconnaissance flight of four to eight hours by fixed-wing aircraft, had located concentrations of Caribou prior to the survey.

From June 1993 to July 1998 a comprehensive field research program was undertaken on Banks Island. Field camps were established in the Caribou wintering and calving grounds (Figure 2). As part of this program, field trips of 6-21 days in length were conducted six times a year: mid-June, mid-July, mid-August, early November, mid-February, and late-April. The June and July field trips were conducted with Bell 206B or 206L helicopters. The August field trip was conducted with 4 \times 4 ATV's, and the November, February, and April field trips were conducted with snowmachines. We tried to classify into the four sex and age categories all Caribou observed during travel associated with these and other field trips. During July we relocated the helicopter to a camp located by Nangmagvik Lake (74° 6'N \times 120° 0'W) to conduct the annual aerial summer classification survey. Nangmagvik Lake is situated adjacent to the major historical calving and summer range of Banks Island Caribou (Urquhart 1973*, Figure 2). Three to six hour flights were made by helicopter over the calving and summer range and classification proceeded as described previously. In 1994 and 1998, aerial reconnaissance by fixed-wing aircraft involved in the Banks Island population survey iden-

References marked with asterisk () are listed in a separate Documents Cited section following Acknowledgments, all other authors are in Literature Cited.

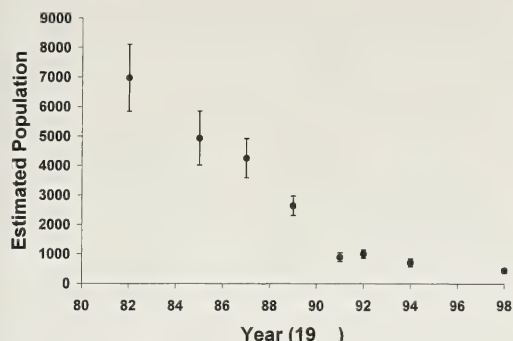


FIGURE 1. Estimated population of Peary Caribou on Banks Island from 1982 to 1998 based upon island-wide surveys. Bars are SE of the estimate.

tified areas of local Caribou concentration in the summering grounds prior to the classification survey. Additional classification data were provided by local hunters and trappers. During the 32 field trips conducted in association with the 1993–1998 study, 1159 classifications of Caribou were made.

We acknowledge that multi-day ground-based classification surveys provide the potential for double counting Caribou. However, when groups were located a precise location was determined by the use of a global positioning system (GPS). We believe that the number of double counted individuals was low and had little, if any effect on our calculations. Local hunters and trappers marked locations of observed Caribou on 1:250 000 maps so that the probability of double counted groups could be assessed. We determined that two groups of mixed sex and age Caribou (numbering 5 and 6 in total) were likely observed and reported by two different hunters. One group of two male Caribou was seen and reported twice by the same hunters. These three groups were only included once in our analysis.

Estimating Calf Production

We discarded classification surveys of fewer than 20 caribou. From the remaining data, we defined our best estimate of calf production as the ratio of calves per 100 adult females determined from the survey(s) conducted in July and August of the year. We had sufficient data from July and August to develop seven annual calf production estimates (1992, 1994–1999). In four years (1982, 1990–1991, 1993) survey data were unavailable during July and August so we used data from surveys conducted during September–November. We realize that these estimates do not address neonatal mortality and estimates derived from November surveys may underestimate productivity more than those derived from only July data, but these were the best data available.

Estimating Overwinter Survival of Calves

We estimated overwinter calf survival by dividing the best estimate of calf production in each year by the best estimate of the ratio of yearlings recorded per 100 adult females in the following year. This estimate assumed female recruitment matched adult female losses. The best estimates of the number of yearlings per 100 adult females were those data available from May – July, when classification of yearlings is easiest.

Partitioning Classification Data

Historical surveys had been conducted at various times of the year and 1993–1998 classification data were collected during six different months of the year. This allowed us to partition survey data into distinct periods associated with the annual cycle of Banks Island Caribou (following the Porcupine Caribou Technical Committee 1993). With the assistance of local hunters and trappers we defined five circannual periods (following Urquhart 1973*; R. Kuptana, A. Carpenter, and J. Lucas Sr. personal communication): calving (May and June), summer (July and August), fall/rut (September through 10 November), winter (11 November through March), and pre-calving (April).

For each circannual period from each year with ≥ 20 caribou classified ($n = 29$) we calculated the ratio of calves per 100 adult females, ratio of yearlings per 100 adult females, percent calves, and percent yearlings. All groups, even those with unclassified adults, were included in our calculations. For groups with unclassified adults, we calculated the maximum range of the ratios of calves and yearlings per 100 adult females by determining the ratio if all unclassified adults were assumed males, and conversely if all unclassified adults were assumed females. The mid-range value of these ratios was used in the statistical analyses.

Winter Snow Measures

We defined severe winter as freezing rains in early winter that caused die-offs of caribou. Accounts of severe winter weather events prior to winter 1992–1993 have been documented previously (Nagy et al. 1996). We documented severe winter weather events from 1993 to 1999.

Caribou on Banks Island generally crater in upland habitats and in areas where snow is less deep and hard (Larter and Nagy in 2001). We used mean winter snow depth and hardness pooled across upland habitats (UB, HT, and SB) as indices of relative winter severity. We measured snow conditions in each habitat in caribou winter range during early (31 October–14 November), mid- (18–22 February) and late- (21–29 April) winter from October 1993 to April 1998 except for winter 1993–1994 when we were unable to take mid-winter measurements. Ten stations were located along fixed transects in each

TABLE 1. All classification data including those that were used to best estimate the overwinter survival (%) of Peary Caribou calves on Banks Island from 1991 to 1998: the survey month(s) classification data were collected, the actual number of calves, yearlings (yrlns) and 2+ year old females classified and their accompanying ratios/100 2+ year old females, and the best estimate of overwinter survival.

Year	Survey Month(s)	Calves		Yearlings the Following Year			Overwinter Survival (%)
		# calves/ # 2+year females	calves/100 2+year females	Survey Month(s)	# yrlns/ # 2+year females	yrlns/100 2+year females	
1982–1983	November 1982	31/41	75.6				
1990–1991	October 1991	20/38	52.6				
1991–1992	September– November 1991	13/22	59.1	June 92	4/29	13.8	23
1992–1993	August 1992	58/85	68.2	May–June 93	20/47	42.6	62
1993–1994	October– November 1993	18/43	41.9	July 94	9/25	36.0	86
1994–1995	July–August 1994	6/25	24.0				
1995–1996	July–August 1995	8/15	53.3	July 96	4/12	33.3	62
1996–1997	July 1996	8/12	66.7	July 97	4/15	26.7	40
1997–1998	July–August 1997	10/23	43.5	July 98	16/70	22.9	53
1998–1999	July 1998	52/70	74.3	July 99	25/78	32.1	43
1999–2000	July 1999	55/78	70.5				

habitat. Five measurements of snow depth (cm) and hardness (kg • cm) were taken at each station using a Swiss Rammsonde penetrometer (Ager 1965; Raillard 1992; Larter and Nagy 1994*).

We used correlation analysis to determine if there were significant relationships between calf production or overwinter survival and mean winter snow depth or hardness from winter 1993–1994 to 1997–1998.

Statistical Analyses

For the 29 different circannual-by-year surveys we used a Kruskal-Wallis test to determine if there were year or circannual period effects on: calves:100 adult females, yearlings:100 adult females, percent calves, or percent yearlings. If Kruskal-Wallis tests indicated significant results, multiple comparisons (Gibbons 1985) were conducted on the mean class ranks

TABLE 2. Median ratios of calves per 100 adult females (ca/100fem), and percent (%) calves in the survey from all circannual periods in which classification surveys were conducted on Banks Island. N = the total number of animals classified.

Year		Calving	Summer	Fall/Rut	Winter	Pre-Calving
1982	ca/100fem (N)				72.3 (113)	
	% calves				27.4	
1990	ca/100fem (N)			48.4 (104)		
	% calves			19.2		
1991	ca/100fem (N)			78.2 (38)	33.3 (33)	
	% calves			21.1	15.2	
1992	ca/100fem (N)	58.6 (60)	68.2 (191)		42.9 ¹ (18)	
	% calves	28.3	30.4		16.7 ¹	
1993	ca/100fem (N)	12.5 (114)	33.3 (16)	33.3 (60)	21.6 (139)	26.2 ¹ (17)
	% calves	6.1	12.5	20.0	10.8	17.6 ¹
1994	ca/100fem (N)	20.0 (23)	24.0 (47)		16.3 (88)	48.6 ¹ (18)
	% calves	4.3	12.8		12.8	22.2 ¹
1995	ca/100fem (N)	100.0 ¹ (2)	35.7 (52)	75.0 (21)	65.4 (46)	64.2 (23)
	% calves	50.0 ¹	15.4	14.3	32.6	30.4
1996	ca/100fem (N)		49.4 (47)	71.4 (29)	69.2 (59)	76.9 (31)
	% calves		17.0	34.5	30.5	32.3
1997	ca/100fem (N)	47.2 (37)	41.8 (75)	75.0 ¹ (9)	46.5 (117)	
	% calves	21.6	13.3	33.3 ¹	16.2	
1998	ca/100fem (N)	40.0 (20)	74.3 (162)		42.8 (69)	20.0 (23)
	% calves	13.6	32.1		23.2	8.7
1999	ca/100fem (N)		70.5 (174)			
	% calves		31.6			

¹Not used for the Kruskal-Wallis analysis.

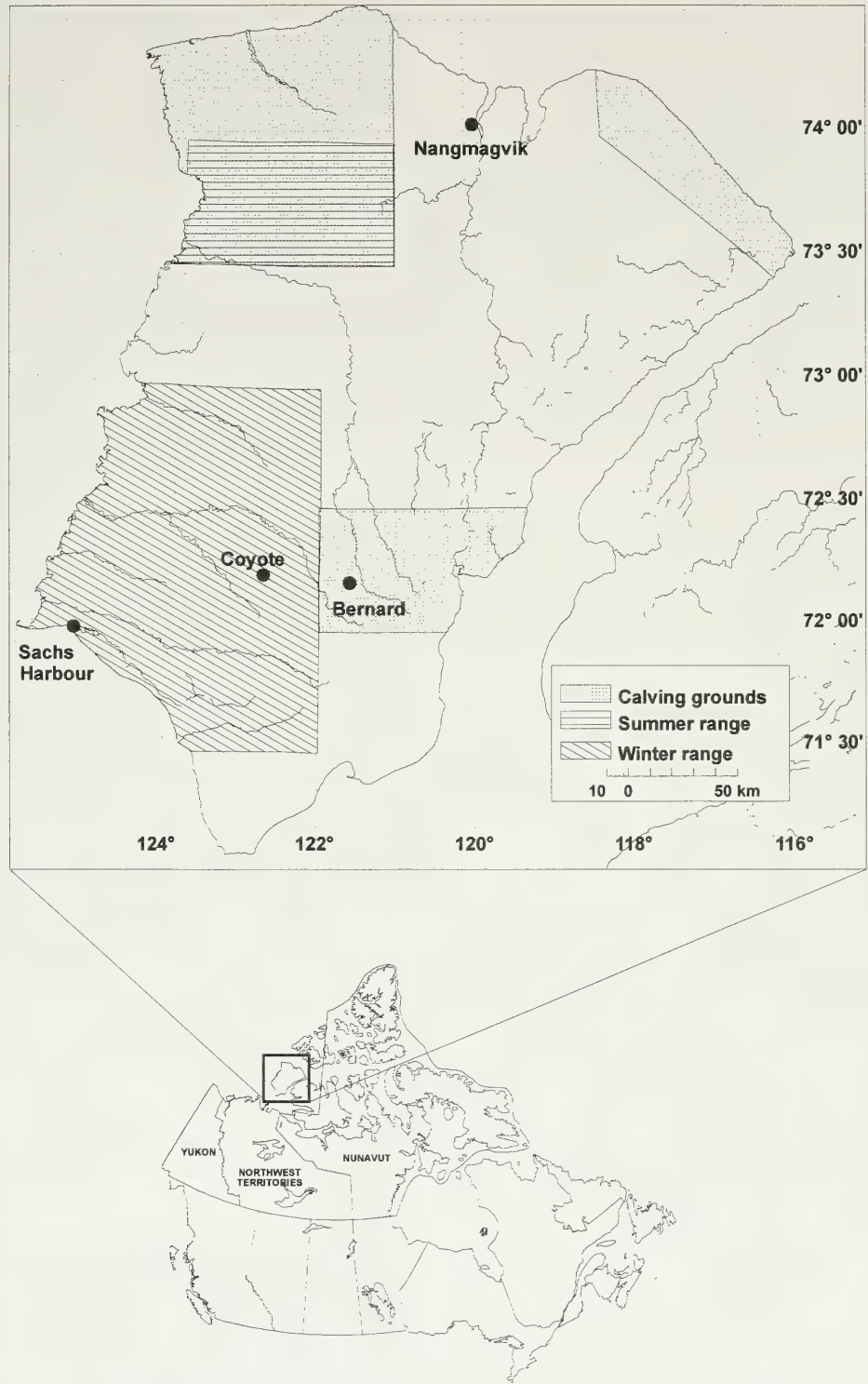


FIGURE 2. Banks Island in the Canadian High Arctic with the traditional Peary Caribou calving grounds, winter, and summer ranges (based upon Urquhart 1973*), and field camp locations indicated.

to identify significantly different subsets of years. We used an overall significance level of 0.25 for multiple comparisons.

Results

Calf Production

We estimated calf production for 11 years (Table 1). Calf production ranged from 24.0 to 75.6 calves per 100 adult females. In eight of 11 years production was > 50.0 calves per 100 adult females. Years of low calf production were 1993, 1994, and 1996.

Overwinter Survival

We estimated overwinter survival of calves for seven years: 1991–1992, 1992–1993, 1993–1994, 1995–1996, 1996–1997, 1997–1998, and 1998–1999 (Table 1). Overwinter survival ranged from 23 (1991–1992) to 86% (1993–1994). In four of seven years overwinter survival was $> 50\%$. 1991–1992, 1996–1997, and 1998–1999 were years of low overwinter survival of calves.

Classification Data

We used data from eight summer and winter periods, five calving and fall/rut periods, and three pre-calving periods to test for year and circannual effects on classification data. Year effects on the ratios of calves per 100 adult females showed marginal significance ($P=0.06$). There were no year or circannual effects on percent calves, percent yearlings, or the ratios of yearlings per 100 adult females ($P>0.17$). The ratios of calves per 100 adult females were similar in 1995, 1996 and 1999 and significantly higher than those ratios found in 1993 and 1994; ratios in 1993 and 1994 were similar (Table 2). Median values for the ratio of calves per 100 adult females pooled across circannual periods ranged from 22.0 in 1994 to 72.3 in 1982.

Winter Snow Measures

Severe winter weather events occurred during winters 1987–1988, 1988–1989, and 1990–1991. Freezing rains also occurred in early winter 1993–1994. Although mean snow hardness was orders of magnitude greater in 1993–1994 than in following winters no caribou die-off occurred. Calf production was lowest following the winter with the hardest snow but there was no significant relationship between snow hardness and calf production. Overwinter survival of calves had a positive relationship ($P=0.042$) with snow hardness, however when outlying data from 1993–1994 were removed there was no relationship ($P=0.30$, Figure 3a). Calf production was highest following the winter with shallowest snow but there was no relationship between either calf production or overwinter survival and mean snow depth ($P>0.23$, Figure 3b).

Discussion

Calf Production

Calf production showed substantial annual vari-

ability, part of which may be attributed to variation in survey dates. However, large annual fluctuations in fecundity and pregnancy rates have been documented for Peary Caribou elsewhere (Thomas et al. 1976, 1977; Thomas and Broughton 1978; Thomas 1982) and for Svalbard Reindeer (*Rangifer tarandus platyrhynchus*) (Tyler 1987, Table 3). Because data are lacking from the 1980s when the population was much larger (ca. 2500–7000 non-calves, Figure 1), we can only speculate that current calf production and its annual variability are representative of levels found when the population was substantially larger.

From 1993–1999 calf production was higher ($P<0.05$) in 1995, 1996, and 1999 than in 1993 and 1994 and continued higher in 1997 and 1998 ($P<0.10$, Table 2). A number of population surveys have been conducted on many of the Arctic islands; these provide a larger historical data set on percent calves in the population and provide an alternative index of fecundity. These data also show large annual fluctuations, both within islands (Fischer and Duncan 1976*; Tyler 1987; J. Nagy and N. Larter unpublished data) and among islands (Tener 1963; Fischer and Duncan 1976*; Miller 1992). Percent calves during summer from this study (12.5–32.1) are similar to those found elsewhere (Table 4). Percent calves in 1993 and 1994 were lower than those in subsequent years 1995–1999 (Table 2). The 1994 percentage is the second lowest recorded of seven surveys conducted between 1982 and 1994 on Banks Island; calf production in 1994 was the lowest of the 11 years with data (Table 1). These data all point to low fecundity during 1993–1994 on Banks Island.

Although severe winter weather has been implicated as a major factor in high variability of calf production the sex and age structure of a small population cannot be discounted as a factor for the Banks Island population. Throughout the 1980s harvest was female selective (J. Nagy and N. Larter unpublished data). Such harvesting, combined with winters with die-offs, likely resulted in a population with a male bias skewed toward younger animals. The age of harvested males from 1990–1998 indicates a harvest skewed to younger males (N. Larter and J. Nagy unpublished data). Such population characteristics in the early 1990s may have been a factor in reduced productivity and greater variability.

Overwinter Survival

High pregnancy rates and production do not translate into high recruitment. Studies on caribou and reindeer populations have shown that calf mortality is one of the main factors affecting population growth (Bergerud 1971; Parker 1972; Skogland 1985; Tyler 1987). Tyler (1987) found that most of calf mortality for Svalbard Reindeer occurred in late-winter regardless of female fecundity levels. We found substantial annual variability in overwin-

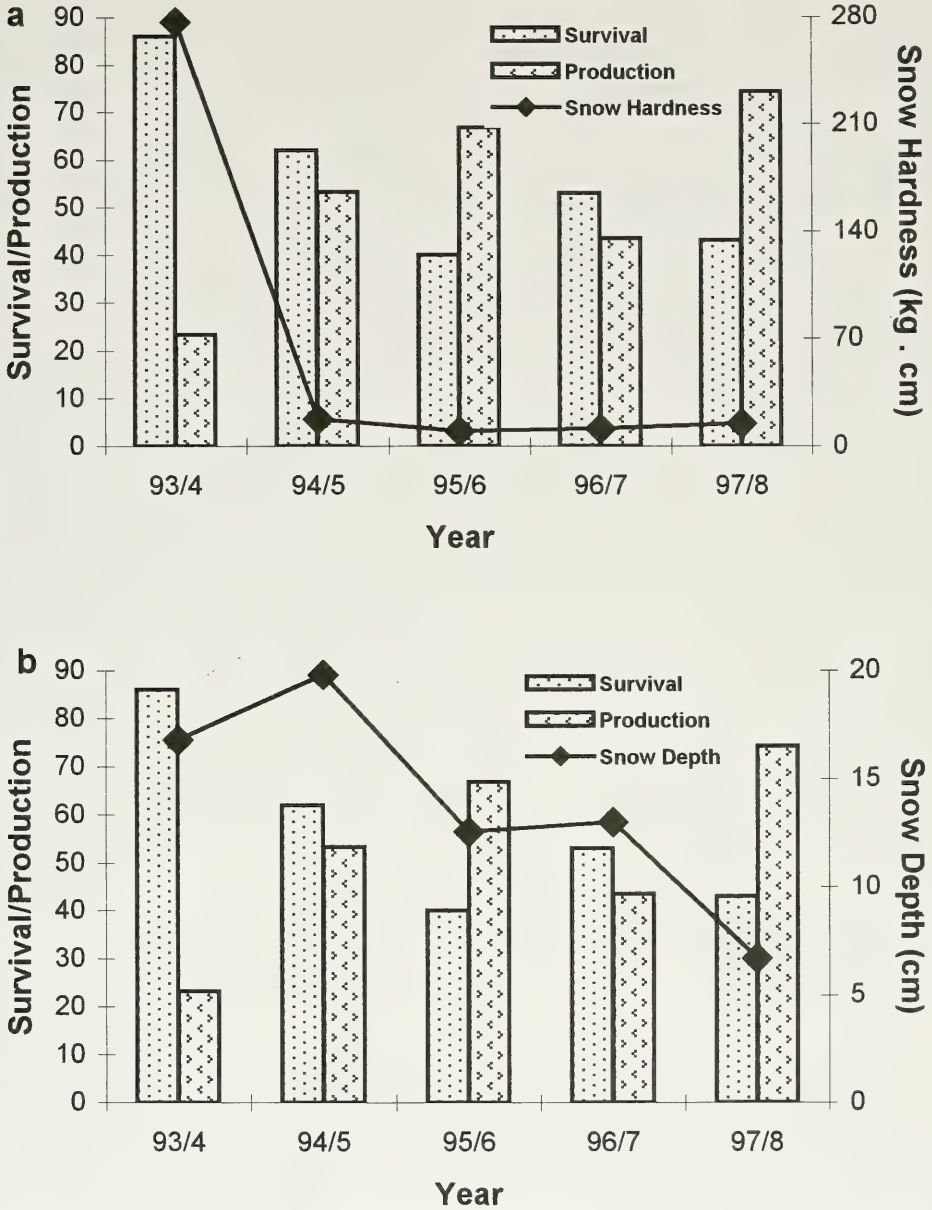


FIGURE 3. Overwinter survival and calf production the following summer for years 1993–1994 to 1997–1998 plotted against a) mean annual snow hardness (kg · cm), and b) mean annual snow depth in upland habitats.

ter survival of calves on Banks Island, ranging from 23 to 86%. Survival was lowest during winter 1991–1992; the winter following the recorded 1990–1991 winter die-off of at least 60 Caribou (Nagy et al. 1996). Reduced overwinter survival a year after a severe winter may be indicative of cohort differences in survival and age at first reproduction (Albon et al. 1987) resulting from the com-

bination of the previous year's unfavourable weather and female biased harvest. The highest overwinter survival occurred during winter 1993–1994 when fall icing conditions were documented on a substantial proportion of the caribou winter range (Larter and Nagy 1994*). If overwinter mortality of adult females was markedly higher relative to other animals in 1993–1994 than in other years then our

TABLE 3. Comparative ratios of calves per 100 adult females determined from summer (July and August) classification surveys of Svalbard Reindeer (first row) and Peary Caribou (rows 2-4).

Location	Year(s)	Ratio	Reference
Svalbard	1979–1984	9.0–73.3	Tyler 1987
Bathurst Island Archipelago	1990	44.4–88.2	Miller 1992
Banks Island	1993–1999	24.0–74.3	This study
Melville Island	1998–1999	44.8–80.0	Larter and Nagy 2000b*

estimate of overwinter survival could have been inflated.

We feel that misclassification of yearlings in surveys conducted during May and June is minimal. The potential for misclassifying yearlings increases during fall and winter. However if there was an increase in misclassification over time, that bias was relatively constant throughout this study because the estimates of yearlings per 100 adult females and percent yearlings from 1993–1999 were based upon classifications by the same individual (NL).

There are no comparable data on overwinter survival of Peary Caribou from elsewhere. Tener (1963) reported percent yearlings on the Queen Elizabeth Islands in 1961 ranged from 0.0–8.1 (median 4.3). Median percent yearlings was approximately one-fifth of the median percent calves he reported for that year. Assuming similar productivity in 1961 and no major loss of adults, overwinter survival could be estimated at 20%, much lower than we report.

Winter Weather

Large annual fluctuations in fecundity of both Peary Caribou and Svalbard Reindeer have occurred independently of population density, suggesting that weather likely affected the rates, and severe winters in particular (Thomas 1982; Tyler 1987; N. Tyler personal communication). However, Tyler et al.

(1999) concluded that the instability of Svalbard Reindeer in Adventdalen, over 20 years, was of both density-dependent and density-independent variation in fecundity and survival. Severe winter weather undoubtedly has some effect on delaying certain cohorts from reaching a certain weight and/or size that may be necessary in order to conceive.

Severe winter weather caused die-offs on Banks Island during winters 1987–1988, 1988–1989, and 1990–1991 (Nagy et al. 1996); unfortunately production and overwinter survival data during this period were lacking. Icing conditions over much of the traditional Caribou winter range during winter 1993–1994 did not result in a die-off. A limited number of calves and adult males collected in November 1993 and February 1994 were deemed to be in similar condition to Caribou commonly seen at this time of year by local residents of Sachs Harbour. Based upon measures of body condition indices, they were of similar condition to Caribou from elsewhere (Larter and Nagy 1996*). The lack of a winter die-off given severe icing over a substantial portion of the traditional wintering grounds imply that there was adequate forage accessible to sustain current Caribou densities (Larter and Nagy 1994*). However, the lowest recorded calf production (24.0 calves per 100 adult females) occurred the following summer possibly

TABLE 4. Calf percentages for Svalbard Reindeer (first row) and various Peary Caribou populations. Percentages were calculated from summer (July and August) classification and population surveys.

Population/Location	Year(s)	% Calves	Reference
Svalbard	1979–1984	3.7–27.3	Tyler 1987
Banks Island	1993–1999	12.5–32.1	Classification surveys, this study
Banks Island	1994	7.5	J. Nagy and N. Larter unpublished data
Banks Island	1992	30.0	J. Nagy unpublished data
Banks Island	1991	5.4	Fraser et al. 1992*
Banks Island	1989	25.5	McLean and Fraser 1991*
Banks Island	1987	22.6	McLean 1991*
Banks Island	1985	16.6	McLean et al. 1986*
Banks Island	1982	25.0	Latour 1985*
Banks Island	1971–1972	17.3–27.9	Urquhart 1973*
North Banks Island	1970	19.1	Kevan 1974
Melville Island	1998–1999	17.6–26.0	Larter and Nagy 2000b*
Bathurst Island Archipelago	1990	15.7–19.6	Miller 1992
Parry Islands	1975	17.0–35.0	Fischer and Duncan 1976*
Parry Islands	1974	0.0–28.0	Fischer and Duncan 1976*
Queen Elizabeth Islands	1961	10.8–29.7	Tener 1963

indicating that severe winter had negatively affected calf production.

Calf production from 1993–1994 to 1997–1998 tended to be higher in years following winters with shallower snow, being highest (74.3 calves per 100 adult females) in 1998. The 1997–1998 winter had the lowest snow depth and was one of the mildest in recent years (Larter and Nagy in 2000a*, R. Kuptana personal communication). The 1995–1996 and 1996–1997 winters were both relatively less severe than 1993–1994 and 1994–1995 (Larter and Nagy in review; R. Kuptana personal communication), however there was no clear correlation with calf production or overwinter survival.

Survey dates from 1993–1999 had little variability therefore they should not influence any relationship that may exist between snow measures and production and overwinter survival. Possibly we lack sufficient variability in winter severity over this period to detect any relationships. Alternatively, variation in production and overwinter survival is not solely in response to winter severity measured as either snow depth or hardness. The high levels of calf production in 1998 and 1999 are similar to those in 1982 and may be representative of more normal levels for Banks Island Caribou.

Ratio data cannot estimate population trend (Caughley 1974). Despite seemingly high calf production and overwinter survival, less severe winter snow conditions, and an extremely restricted harvest, numbers of Peary Caribou on Banks Island were lower in 1998 than 1994 ($P < 0.10$). Arctic Wolves prey upon both Peary Caribou and Muskoxen on Banks Island (Nagy and Larter 2000). The traditional Caribou calving and summering grounds are located adjacent to the highest density of Wolf dens, and Wolves in packs of up to 20 animals are often seen in this area during summer (N. Larter and J. Nagy unpublished data). Non-selective predation on calves, yearlings, and adult females on the summer range, and as Caribou migrate in a southerly direction by this high density Wolf area in fall could cause declining numbers while maintaining indices of high production and overwinter survival. Currently, data on the summer diet of Wolves in this area are limited.

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Extra-limital Observations of Broad-winged Hawk, *Buteo platypterus*, Connecticut Warbler, *Oporornis agilis*, and Other Bird Observations From the Liard Valley, Northwest Territories.

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Machtans, Craig S. 2000. Extra-limital observations of Broad-winged Hawk, *Buteo platypterus*, Connecticut Warbler, *Oporornis agilis*, and other bird observations from the Liard Valley, Northwest Territories. Canadian Field-Naturalist 114(4): 671–679.

Eight records of Broad-winged Hawk (*Buteo platypterus*) and six records of Connecticut Warbler (*Oporornis agilis*) are presented from the lower Liard Valley, Northwest Territories. An active Broad-winged Hawk nest was found (most northerly breeding record), along with evidence that breeding has been attempted in at least three previous years. The Connecticut Warbler records (most northerly published) do not provide any evidence of breeding. A compiled list of 157 species observed in the same area is also presented, as many species are at or near the edge of their ranges there and recent industrial development is increasing the need for more detailed biological information. Annotations are included for several species that are slightly beyond their published ranges or are of particular interest.

Key Words: birds, range, distribution, Liard Valley, Broad-winged Hawk, *Buteo platypterus*, Connecticut Warbler, *Oporornis agilis*, Northwest Territories, Canada.

The Liard Valley occupies the extreme southwest corner of the Northwest Territories (Figure 1). The regional bird fauna is an interesting and rich assemblage of species, and includes several that are at or near their western and/or northern range limits. Eastern species such as Rose-breasted Grosbeak (*Phœucticus ludovicianus*), Bay-breasted Warbler (*Dendroica castanea*), and Canada Warbler (*Wilsonia canadensis*) share habitats with western species such as Varied Thrush (*Ixoreus naevius*) and Hammond's Flycatcher (*Empidonax hammondii*). They are all members of a bird community that can reach high relative densities (e.g. up to 29 birds on a 10 minute, unlimited distance point count in extensive forest, CSM unpublished data).

There has been very little previous bird research in the area. Regionally, Erskine and Davidson (1976) report a similar list of species from the Fort Nelson area of northeastern British Columbia. They also reported 157 species; 129 were common to the list here, including Connecticut Warbler (*Oporornis agilis*), but not Broad-winged Hawk (*Buteo platypterus*). North of the Liard area, in Nahanni National Park, Scotter et al. (1985) reported 129 species in common. Neither Connecticut Warbler or Broad-winged Hawk were reported in their study area.

Locally, one Breeding Bird Survey route was conducted along the Liard Highway during 1989–1992 (restarted by the author in 1998). An ethnographic study that included an appendix on bird observations was conducted in the vicinity of Fisherman Lake (Lamont 1977; Figure 1). Greenberg and Sterling

(1997*) and Greenberg et al. (1999) conducted point counts in some habitats, and Eckert et al. (2000*) collected bird data for five years, immediately to the west, in the Yukon. Forestry and petroleum development in the area has resulted in many environmental assessment reports being compiled, but no explicit bird surveys were conducted for the projects.

The increased level of development and the diversity of the local bird community underlies the need for more detailed biological information. The Canadian Wildlife Service (CWS) started a forest songbird project in the area in 1998 in response. The study area is >700 km² and uses 195 point counts to survey the range of habitats that are accessible from the one public road in the area along the east side of the Liard River.

This paper reports on multiple observations of Broad-winged Hawk and Connecticut Warbler obtained during the CWS study. The accepted northern limit of the breeding range of the Broad-winged Hawk is the Peace River area of British Columbia (AOU 1998), about 600 km south of these observations. The same limit for the Connecticut Warbler is 150 km south, near Fort Nelson, in northeastern British Columbia (AOU 1998). In addition, a list of 157 species identified in the area has been compiled based on a literature review, the previous work noted above, and incidental observations while in the area for the current CWS study. This inventory extends

*See Documents Cited section

the ranges of some other species slightly from previously published accounts and provides the most complete list of species for that portion of the Northwest Territories.

Study Area

The local area is characterized by relatively warm summers and winters for the latitude, and also has relatively high precipitation. Annually, Fort Liard (60°15'N, 123°30'W; Figure 1) is almost 2°C warmer and receives 30% more precipitation than nearby Fort Simpson (200 km north; Environment Canada 1982). As a result of these conditions and other physiographic features, the forests are boreal mixed-wood and achieve a vigour similar to areas much farther south. The local forests are primarily composed of pure and mixed stands of White and Black spruce (*Picea glauca* and *P. mariana*), poplar species (*Populus tremuloides*, *P. balsamifera*) and White Birch (*Betula papyrifera*) of varying ages. Wetter areas have short, open forests of Larch (*Larix laricina*) and Black Spruce. Old stands (broken canopies, typically 120+ years old) often attain heights of >30 m (tree heights >40 m have been recorded) and diameter-at-breast-height (dbh) is often >50 cm on large trees, with some old, riparian poplars exceeding 100 cm dbh (CSM unpublished data). The dominant natural disturbance factors in the region are fire, blow-down, and insect outbreak (Spruce Budworm, *Choristoneura fumiferana*). As is typical of old boreal stands, large canopy gaps allow dense tall-shrub layers to develop (mostly alder, *Alnus* spp., and willow, *Salix* spp.). In addition to the forests, there are wetland complexes, open bogs/fens, alpine areas and several large lakes and rivers. Consequently, there is a great diversity of habitats available for birds.

For the list of birds presented in the appendix, observation records are from the British Columbia border to 60°42' N, bounded by the first set of mountains to the west of the Liard River and within approximately 6 km east of the Liard Highway (Figure 1, lower). All observations of Broad-winged Hawk and Connecticut Warbler come from the east side of the Liard River.

Broad-winged Hawk

The recognized continuous breeding range for Broad-winged Hawk extends into east-central British Columbia from areas farther east and south (Goodrich et al. 1996; AOU 1998). The American Ornithologists' Union Checklist (1998) indicates a casual status in the northern part of the provinces and the recent Birds of Alberta (Fisher and Acorn 1998) maps the range as extending throughout northwestern Alberta. The species has been reported several times in the Peace River area of British Columbia (Campbell et al. 1990), including recent breeding records (W. Campbell, personal communication),

with one record farther north, near Fort Nelson. In June 1999, a bird was identified and photographed at a similar latitude as these observations, but farther east and just south of the Northwest Territories/Alberta border near Fort Smith (60°00' N, 112°00' W, M. Bradley, personal communication). Semenchuk (1992) shows one observation at Bistcho Lake in the extreme northwest corner of Alberta and additional non-breeding records in northeastern Alberta, along the Slave River, complementing observations in Nero (1963) and Salt and Salt (1976) near Lake Athabasca. Additionally, there is one record for the Northwest Territories, at Fort Simpson on 23 May 1973 (61°51' N, 121° 21' W) (Salter et al. 1974) (this is the record in Sirois and McRae [1996]). However, there was no conclusive breeding evidence for areas north of east-central British Columbia.

In the southeast Yukon, one individual was observed by Cameron D. Eckert on 15 June 1997. It was approximately 4 km north of the British Columbia border in the drainage of the lower La Biche River, immediately west of the Northwest Territories/Yukon border. The bird was perched and vocalizing and was found in mature to old aspen forest surrounded by old mixedwood forest. This record was reviewed and accepted by the Yukon Bird Records Committee.

Eight separate observations of Broad-winged Hawk (Table 1) were made during 1998–2000 in the Liard Valley. Several sightings were at close range where the bird was perched and vocalizing, making identification straightforward for experienced observers. One bird was in dark-phase plumage, while the others were of typical appearance. The birds were usually observed in mature or old mixed-wood forests, within 800 m of a water body, and within 3 km of the Liard River.

Local breeding was confirmed for this species in 2000 by the discovery of an active nest (last record in Table 1). In addition, three inactive nests within 260 m of the active nest were noted and all are described in Table 2; it is assumed these are old nests within the territory of the current pair. The active nest was observed from a blind for approximately 2.5 hours. One bird (sex unknown) returned to the nest within 15 minutes of the initial disturbance of blind placement. The bird stayed on the nest (unattended) for the duration of the observation period, presumably incubating.

The three old nests indicate probable breeding activity for at least the past three years in the area, since Broad-winged Hawks tend to build a new nest annually (Goodrich et al. 1996). The area supports abundant amphibian (Chorus Frog, *Pseudacris triseriata maculata*, Wood Frog, *Rana sylvatica*, and Boreal Toad, *Bufo boreas*) and small mammal populations, and the forest is typical of that found in the hawk's breeding range in central Alberta (personal

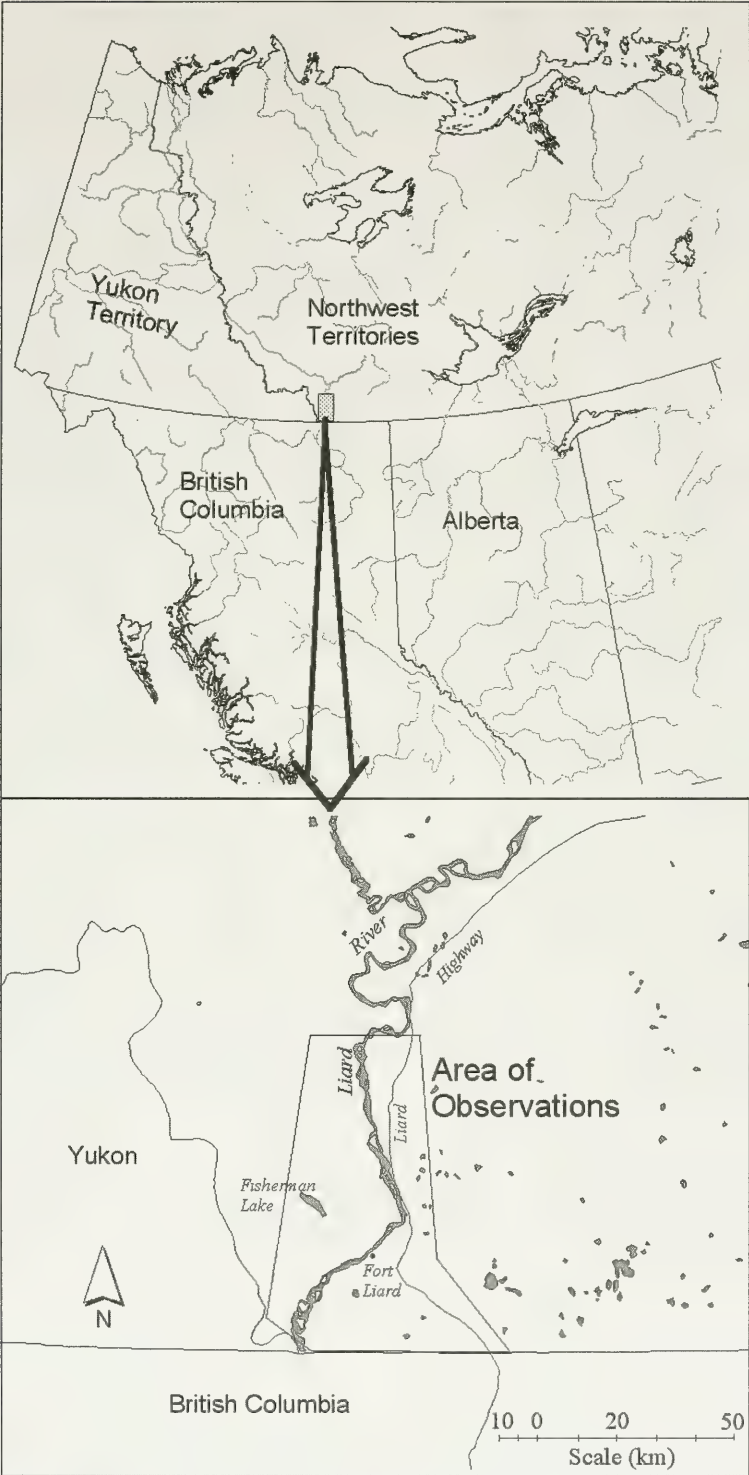


FIGURE 1. Location of study area in Liard Valley, Northwest Territories, Canada (black box on upper, outlined area on lower).

TABLE 1: Details of Broad-winged Hawk observations in the Liard Valley, Northwest Territories.

Date (observer)‡	Location	Habitat	Notes
26 May 1998 (CM)	60°15'01", 123°24'41"	Mature mixedwood	Dark-phase bird seen gliding at canopy level
12 August 1998 (CB)	60°22'18", 123°19'50"	Old mixedwood	Perched bird vocalizing
9 June 1999 (CB)	60°30'36", 123°26'02"	Not recorded	Very quick views of bird in flight, not certain ID
22 June 1999 (CM)	60°19'55", 123°20'32"	Mature mixedwood	Perched bird vocalizing, flew short distances as approached
25 June 1999 (BO)	60°13'19", 123°29'12"	Mature mixedwood	Bird flew in, perched and vocalized
20 July 1999 (BO)	60°27'21", 123°26'07"	Old growth spruce	Bird identified by vocalizations, not directly observed
31 May 2000 (TH)	60°14'46", 123°24'47"	Mature mixedwood	Perched, visual ID
8 June 2000 (TH)	60°13'09", 123°29'26"	Mature mixedwood	Two birds seen, begging calls heard in vicinity (in area of active nest)
17 June 2000 (CM)	60°13'13", 123°29'48"	Mature mixedwood	Adult bird seen carrying small mammal prey (in area of active nest)
24 June 2000 (GB)	60°13'12", 123°29'42"	Mature mixedwood	Active nest in territory area of 3 preceding observations and of observation on 25 June 1999

‡CM = author, CB = Carl Burgess, BO = Ben Olsen, TH = Todd Heakes, GB = Gerry Betthale

observation). These factors, taken together with observations of multiple birds across several years, seem to indicate the presence of a local breeding population. It is worthwhile to note that suitable habitat is patchily distributed this far north, so broad generalizations about range distributions are difficult (A. J. Erskine, personal communication).

Connecticut Warbler

The published northern and western range limits of the Connecticut Warbler are similar to those for the Broad-winged Hawk (Pitocchelli et al. 1997; AOU 1998; National Geographic 1999). The upcoming Birds of British Columbia account for Connecticut Warbler (Campbell unpublished*) indicates a confirmed breeding record for the Fort Nelson area (~160 km south of Fort Liard), with many local observations (including one from Erskine and Davidson [1976]). All of the British Columbia records indicate small, localized populations rather

than widespread occurrence. There are no published breeding records in Alberta for similar latitudes, but Semenchuk (1992) shows non-breeding observations as far north as Fort Vermillion (also noted in the area in 1996, B. McGillivray personal communication). In general, confirmed breeding records for Connecticut Warbler make up a small minority of all reported sightings. This is generally attributed to the secretive nature of both sexes around their nest, in contrast to the boisterous song of the male.

The six records from the Liard Valley were a mix of auditory and visual observations (Table 3). The first local observation was by song, recorded with a parabolic microphone. Subsequently, visual confirmation was obtained for three records. In all cases, the observations were of singing males.

Observers invested time looking for any evidence of paired status. No females or any behaviours that would be indicative of breeding were noted during approximately three hours of close observation of

TABLE 2. Nest site characteristics of Broad-wing Hawk nests found within one territory, Liard Valley, Northwest Territories. The last record is the active nest described in the text; there is no absolute guarantee that the inactive nests were not from another raptor in the area, though that is unlikely. All nests are from a mixedwood stand that is at least 165 years old based on ages from tree coring.

Tree Species	Nest Height (Tree Height) (m)	Tree Diameter at Breast Height (cm)	Distance to Wet Area (m)	Distance to Opening (m)
<i>Populus tremuloides</i>	17.75 (28.5)	49	260	5(55)†
<i>Populus tremuloides</i>	18.0 (33.5)	65	240	25(50)†
<i>Populus tremuloides</i>	22.0 (35.5)	78	250	100
<i>Picea glauca</i>	24.5 (28.0)	38	295*	100

*Distance to a nearby creek with anthropogenic clearings around it, while the other three are distances to the Liard River.

†Values in parentheses are the distance to the nearest opening before a recent, small clearing was made in the territory (present since 1999 breeding season); it is assumed that at least two of the three inactive nests are older than the current opening. The other two nests are closer to openings that have been present for many years.

TABLE 3. Details of Connecticut Warbler observations in the Liard Valley, Northwest Territories.

Date (observer)‡	Location	Habitat	Notes
15 June 1998 (PL)	60°16'13", 123°21'36"	Black Spruce	Song recorded, no visual confirmation
6 June 1999 (CM)	60°15'26", 123°26'14"	Mature mixedwood	Song/Visual ID; 4 observers; still present >10 days from initial sighting; observed for 1 hour, no female sighted
13 June 1999 (MN)	60°16'13", 123°21'36"	Black Spruce	Song/Visual ID, observed for 1h, no female sighted
13 June 1999 (MN)	60°16'28", 123°21'07"	Black Spruce	Song/Visual ID; still present on 16 June, observed for 1hour, no female sighted
17 June 1999 (CM)	60°31'59", 123°27'54"	Mature Aspen	Song ID, on Fort Liard Breeding Bird Survey route
13 June 2000 (JD)	60°16'34", 123°21'45"	Mature mixedwood	Song ID

‡PL = Paul Latour, CM = author, MN = Michael Norton, JD = Jason Duxbury

three birds. However these observations were not obtained at the time of year when parents would be feeding young, hence missing the easiest method of confirming breeding for this species.

The Connecticut Warbler is known to shift its habitat preferences between western (drier sites with aspen) and eastern (wetter sites with spruce/tamarack) portions of its range. The records from north-eastern British Columbia (Campbell unpublished*) describe aspen with a spruce sapling understorey as the preferred habitat. This is similar to the habitat used in central Alberta (personal observation). In contrast, observations in the Liard Valley were from three distinct habitat types (Table 3). However, A. J. Erskine (personal communication) notes that he has observed similarly disparate habitat use at the periphery of this warbler’s range.

Based on the sporadic habitat use, the lack of breeding evidence, and the fact that most records were from 1999 (all of which were from areas visited in 1998 and 2000), there does not appear to be sufficient reason to believe the species is breeding in the area. In contrast to the rather secretive Broad-winged Hawk, Connecticut Warblers are easy to identify from long distances owing to the male’s loud and distinctive song. Therefore, although there are similar numbers of records for the Broad-winged Hawk as the Connecticut Warbler, one might expect to find relatively more of the latter if there was a breeding population in the area. Given the rather local nature and rarity of observations at the periphery of this warbler’s range (noted in AOU 1998), breeding cannot be completely discounted.

Other Noteworthy Sightings

The list of birds identified in the Liard Valley (see Appendix) contains a few species that are at least slightly beyond their normal published ranges (Godfrey 1986; National Geographic 1999) as well as some species of general interest (notes below). The list of 157 species (Appendix) omits several that may be expected to occur in the area or have been

identified in nearby drainages in the Yukon by Eckert et al. (2000*). These are listed in separate categories and will likely be found when suitable habitat is surveyed by birders. These lists focus on potential breeding species, as opposed to the large number of migrants that may pass through the area.

In comparing birds in the appendix to the detailed lists prepared by Erskine and Davidson (1976) and Scotter et al. (1985), it is apparent that the Fort Liard area is the northern range limit for several passerine species. Of the 28 species reported here that were not noted in Erskine and Davidson (1976), they expected to find nearly all of them with additional effort. However, some of those species do not seem to extend their ranges much farther north. Excluding species that were very rare near Fort Liard, Broad-winged Hawk, Cape May Warbler (*Dendroica tigrina*), Canada Warbler (*Wilsonia canadensis*), Connecticut Warbler, Le Conte’s Sparrow (*Ammodramus leconteii*), Cedar Waxwing (*Bombicilla cedrorum*) and Blue-Headed Vireo (*Vireo solitarius*) are all absent from Scotter et al. (1985), but are present in the Fort Liard area and were reported by Erskine and Davidson (1976) (except Le Conte’s Sparrow and the hawk). Also, many of the passerines that are common in the Liard Valley become uncommon or rare in the Nahanni area; Magnolia Warbler (*Dendroica magnolia*), nearly ubiquitous around Fort Liard, is listed as an uncommon summer resident in Nahanni (Scotter et al. 1985).

Below are a few notes on species of general interest or ones that are beyond their currently published limits (Godfrey 1986; National Geographic 1999).

AMERICAN BITTERN (*Botaurus lentiginosus*):

Bitterns have been heard calling in the area by several researchers in different years. This species was not noted in any of the other studies in the local area and is beyond the western limit of its published distribution (Godfrey 1986; National Geographic 1999). Neither Erskine and Davidson (1976) or Scotter et al. (1985) found this species in their areas.

BARRED OWL (*Strix varia*): These owls were so conspicuous and relatively abundant in the area that they deserve mention here. For a species that was poorly known over much of its range until recently, the number in the area was surprising. In two locations, up to three owls were heard counter-calling during the summer months (June and August respectively). In at least one of these instances, a Barred Owl researcher (Ben Olsen) determined the calling individuals were of opposite sexes (a potential pair). In both locations, the observations were made in extensive, mature to old mixedwood stands on the alluvial plains of the Liard River. Eckert et al. (2000*) have not yet noted them in the southeast Yukon, but both Erskine and Davidson (1976) and Scotter et al. (1985) have noted them in the region.

HAMMOND'S FLYCATCHER (*Empidonax hammondii*): This species has been reported by all previous researchers in the area. It is relatively common on the edges of mature spruce forests, especially when they are near water, but there are also records from extensive forest.

CANADA WARBLER (*Wilsonia canadensis*): A common breeder in the old mixedwood forests in the area. Of birds surveyed in mature or old forests (broken canopies with well developed shrub layers), they were one of the 15 most commonly reported species. This species has been reported by all other regional researchers for the area.

TOWNSEND'S WARBLER (*Dendroica townsendi*): Only one was found, and the observation was east of the Liard River, well away from mountainous terrain but on a hillside. The observation was confirmed by recording the unique 2-part call and comparing it to the call of the Black-throated Green Warbler (which has not been recorded in the area). This is one example of a species that may be found to be more common if suitable habitat were surveyed by birders, especially in the mountains immediately west of Fort Liard.

MACGILLIVRAY'S WARBLER (*Oporornis tolmiei*): There are only two observations of this warbler in the area. The first, by R. Ferguson on the Breeding Bird Survey route in 1991 has no supporting documentation, while the second was tentatively identified based on song (also taped) and was also on the BBS route, in the same general area. Further review of the recording by various individuals indicates that the identification is not conclusive, so direct observation of this species is necessary for confirmation in this area. Neither Eckert et al. (2000*) to the west or Scotter et al. (1985) to the north have reported this species. Erskine and Davidson (1976) did not report any breeding season observations, though they note this species

was collected northwest of Fort Nelson during the start of the fall migration period (August).

EVENING GROSBEAK (*Coccothraustes vespertinus*): Though reported by Eckert et al. (2000*) for the area directly west, it was not common in the Liard Valley with only a few records from the recent work by the author and from previous Breeding Bird Surveys. Scotter et al. (1985) do not report any breeding season records, so the northern limit of the breeding range may be in the Fort Liard area, though they appear to have seasonal movements farther north.

Several species were only recorded within the Fort Liard townsite. The hamlet is on the bank of the Liard River and contains many mature poplar trees (more treed than typical settlements) and the adjacent local airstrip and baseball diamonds provide substantial grassland habitat. The species only found (but usually common) in these areas were: Brown-headed Cowbird (*Molothrus ater*), Clay-colored Sparrow (*Spizella pallida*), Brewer's Blackbird (*Euphagus cyanocephalus*), Mourning Dove (casual) (*Zenaida macroura*), Northern Mockingbird (casual) (*Mimus polyglottos*), Eastern Phoebe (*Sayornis phoebe*), Cedar Waxwing, European Starling (*Sturnus vulgaris*) and House Sparrow (*Passer domesticus*).

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Appendix

List of all birds identified in Liard Valley, NWT, near Fort Liard. All species on this list were identified during research by the author or colleagues in 1997–2000 unless otherwise indicated thus: * denotes observations recorded on Breeding Bird Survey route by R. Ferguson, 1989–1992; † denotes observations noted in Appendix 3 of Lamont (1977) not included in the above data. List totals are 145 for probable or known breeders, 10 for migrants (common names in italics), and two for casuals (noted), totaling 157 species. Species names and family orders follow AOU (1998).

Common Loon *Gavia immer*
 Pied-billed Grebe *Podilymbus podiceps*
 Horned Grebe *Podiceps auritus*
 Red-necked Grebe *Podiceps grisegena*
 American Bittern *Botaurus lentiginosus*

†Greater White-fronted Goose *Anser albifrons*

†Snow Goose *Chen caerulescens*

†Ross's Goose *Chen rossii*

Canada Goose *Branta canadensis*

Trumpeter Swan *Cygnus buccinator*

†Tundra Swan *Cygnus columbianus*

American Wigeon *Anas americana*

Mallard *Anas platyrhynchos*

Blue-winged Teal *Anas discors*

Northern Shoveler *Anas clypeata*

Northern Pintail *Anas acuta*

Green-winged Teal *Anas crecca*

Ring-necked Duck *Aythya collaris*

Lesser Scaup *Aythya affinis*

†Surf Scoter *Melanitta perspicillata*

White-winged Scoter *Melanitta fusca*

Bufflehead *Bucephala albeola*

Common Goldeneye *Bucephala clangula*

†Red-breasted Merganser *Mergus serrator*

Ruddy Duck *Oxyura jamaicensis*

Osprey *Pandion haliaetus*

Bald Eagle *Haliaeetus leucocephalus*

Northern Harrier *Circus cyaneus*

Sharp-shinned Hawk *Accipiter striatus*

Northern Goshawk *Accipiter gentilis*

Broad-winged Hawk *Buteo platypterus*

Red-tailed Hawk *Buteo jamaicensis*

Golden Eagle *Aquila chrysaetos*

American Kestrel *Falco sparverius*

Merlin *Falco columbarius*

- Ruffed Grouse *Bonasa umbellus*
 Spruce Grouse *Falcipennis canadensis*
 †Rock Ptarmigan *Lagopus mutus*
 †Blue Grouse *Dendragapus obscurus*
- Sora *Porzana carolina*
 American Coot *Fulica americana*
- Sandhill Crane *Grus canadensis*
- American Golden-Plover *Pluvialis dominica*
 Lesser Yellowlegs *Tringa flavipes*
 Solitary Sandpiper *Tringa solitaria*
 Spotted Sandpiper *Actitis macularia*
 †Least Sandpiper *Calidris minutilla*
 Buff-breasted Sandpiper *Tryngites subruficollis*
 Common Snipe *Gallinago gallinago*
- Bonaparte's Gull *Larus philadelphia*
 Mew Gull *Larus canus*
 Herring Gull *Larus argentatus*
 Black Tern *Chlidonias niger*
- Mourning Dove *Zenaida macroura* (casual)
- Great Horned Owl *Bubo virginianus*
 Northern Hawk Owl *Surnia ulula*
 Barred Owl *Strix varia*
 Great Gray Owl *Strix nebulosa*
 Short-eared Owl *Asio flammeus*
 Boreal Owl *Aegolius funereus*
- Common Nighthawk *Chordeiles minor*
- Belted Kingfisher *Ceryle alcyon*
- Yellow-bellied Sapsucker *Sphyrapicus varius*
 Downy Woodpecker *Picoides pubescens*
 Hairy Woodpecker *Picoides villosus*
 Three-toed Woodpecker *Picoides tridactylus*
 Black-backed Woodpecker *Picoides arcticus*
 Northern Flicker *Colaptes auratus*
 Pileated Woodpecker *Dryocopus pileatus*
- Olive-sided Flycatcher *Contopus cooperi*
 Western Wood-Pewee *Contopus sordidulus*
 Yellow-bellied Flycatcher *Empidonax flaviventris*
 Alder Flycatcher *Empidonax alnorum*
 Least Flycatcher *Empidonax minimus*
 Hammond's Flycatcher *Empidonax hammondi*
 Eastern Phoebe *Sayornis phoebe*
 †Say's Phoebe *Sayornis saya*
 Eastern Kingbird *Tyrannus tyrannus*
- Blue-headed Vireo *Vireo solitarius*
 Warbling Vireo *Vireo gilvus*
 Philadelphia Vireo *Vireo philadelphicus*
 Red-eyed Vireo *Vireo olivaceus*
- Gray Jay *Perisoreus canadensis*
 American Crow *Corvus brachyrhynchos*
 Common Raven *Corvus corax*
- Tree Swallow *Tachycineta bicolor*
 †Bank Swallow *Riparia riparia*
 Cliff Swallow *Petrochelidon pyrrhonota*
 Barn Swallow *Hirundo rustica*
- Black-capped Chickadee *Poecile atricapilla*
 Boreal Chickadee *Poecile hudsonica*
- Red-breasted Nuthatch *Sitta canadensis*
- Winter Wren *Troglodytes troglodytes*
- Marsh Wren *Cistothorus palustris*
- Golden-crowned Kinglet *Regulus satrapa*
 Ruby-crowned Kinglet *Regulus calendula*
- Townsend's Solitaire *Myadestes townsendi*
 †Gray-cheeked Thrush *Catharus minimus*
 Swainson's Thrush *Catharus ustulatus*
 Hermit Thrush *Catharus guttatus*
 American Robin *Turdus migratorius*
 Varied Thrush *Ixoreus naevius*
- Northern Mockingbird *Mimus polyglottos* (casual)
- †American Pipit *Anthus rubescens*
- European Starling *Sturnus vulgaris*
 Bohemian Waxwing *Bombycilla garrulus*
 Cedar Waxwing *Bombycilla cedrorum*
- Tennessee Warbler *Vermivora peregrina*
 Orange-crowned Warbler *Vermivora celata*
 Yellow Warbler *Dendroica petechia*
 Magnolia Warbler *Dendroica magnolia*
 Cape May Warbler *Dendroica tigrina*
 Yellow-rumped Warbler *Dendroica coronata*
 Townsend's Warbler *Dendroica townsendi*
 Palm Warbler *Dendroica palmarum*
 Bay-breasted Warbler *Dendroica castanea*
 Blackpoll Warbler *Dendroica striata*
 Black-and-White Warbler *Mniotilta varia*
 American Redstart *Setophaga ruticilla*
 Ovenbird *Seiurus aurocapillus*
 Northern Waterthrush *Seiurus noveboracensis*
 Connecticut Warbler *Oporornis agilis*
 Mourning Warbler *Oporornis philadelphia*
 MacGillivray's Warbler *Oporornis tolmiei*
 Common Yellowthroat *Geothlypis trichas*
 Wilson's Warbler *Wilsonia pusilla*
 Canada Warbler *Wilsonia canadensis*
 Western Tanager *Piranga ludoviciana*
- *†American Tree Sparrow *Spizella arborea*
 Chipping Sparrow *Spizella passerina*
 Clay-colored Sparrow *Spizella pallida*
 Savannah Sparrow *Passerculus sandwichensis*
 Le Conte's Sparrow *Ammodramus leconteii*
 Fox Sparrow *Passerella iliaca*
 Song Sparrow *Melospiza melodia*
 Lincoln's Sparrow *Melospiza lincolnii*
 Swamp Sparrow *Melospiza georgiana*
 White-throated Sparrow *Zonotrichia albicollis*
 †Harris's Sparrow *Zonotrichia querula*
 White-crowned Sparrow *Zonotrichia leucophrys*
 †Golden-crowned Sparrow *Zonotrichia atricapilla*
 Dark-eyed Junco *Junco hyemalis*
- Rose-breasted Grosbeak *Pheucticus ludovicianus*
- Red-winged Blackbird *Agelaius phoeniceus*
 Yellow-headed Blackbird *Xanthocephalus xanthocephalus*
 Rusty Blackbird *Euphagus carolinus*
 Brewer's Blackbird *Euphagus cyanocephalus*
 Common Grackle *Quiscalus quiscula*
 Brown-headed Cowbird *Molothrus ater*
- Pine Grosbeak *Pinicola enucleator*
 Purple Finch *Carpodacus purpureus*
 Red Crossbill *Loxia curvirostra*
 White-winged Crossbill *Loxia leucoptera*

*†Common Redpoll *Carduelis flammea*
 Pine Siskin *Carduelis pinus*
 Evening Grosbeak *Coccothraustes vespertinus*
 House Sparrow *Passer domesticus*

**Species observed in nearby drainages in southeast
 Yukon but not identified in the Fort Liard Area
 (Cameron D. Eckert, personal communication):**

Red-throated Loon *Gavia stellata*
 Pacific Loon *Gavia pacifica*
 Yellow-billed Loon *Gavia adamsii*
 Cinnamon Teal *Anas cyanoptera*
 Greater Scaup *Aythya marila*
 Common Merganser *Mergus merganser*
 Barrow's Goldeneye *Bucephala islandica*
 Killdeer *Charadrius vociferus*
 Dusky Flycatcher *Empidonax oberholseri*
 Violet-green Swallow *Tachycineta thalassina*

Mountain Bluebird *Sialia currucoides*
 Lark Sparrow *Chondestes grammacus*

**Species reported by Lamont (1977), but as being
 uncertain identifications:**

Great Blue Heron *Ardea herodias*
 Whooping Crane *Grus americana*
 House Wren *Troglodytes aedon* (potentially confused
 with another wren?)

**Species potentially in the area (potential breeders,
 considering National Geographic [1999],
 Godfrey [1986] and available habitat):**

Canvasback *Aythya valisineria*
 Willow Ptarmigan *Lagopus lagopus*
 Sharp-tailed Grouse *Tympanuchus phasianellus*
 Red-necked Phalarope *Phalaropus lobatus*
 Northern Shrike *Lanius excubitor*
 Horned Lark *Eremophila alpestris*

First Record of Kokanee Salmon, *Oncorhynchus nerka*, in Great Slave Lake, Northwest Territories

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Babaluk, John A., James D. Reist, and George Low. 2000. First record of Kokanee Salmon, *Oncorhynchus nerka*, in Great Slave Lake, Northwest Territories. *Canadian Field-Naturalist* 114(4): 680–684.

The first record of a Kokanee Salmon, *Oncorhynchus nerka*, the non-anadromous form of Sockeye Salmon, from the Northwest Territories is reported. The specimen was captured in Great Slave Lake near Hardesty Island (61°44'N, 114°37'W) in the commercial fishery in 1991.

Key Words: Kokanee Salmon, *Oncorhynchus nerka*, first record, Great Slave Lake, Northwest Territories, otolith, proton microprobe, scale.

The Pacific Salmon, *Oncorhynchus nerka*, is distributed throughout the northern Pacific Ocean and occurs as two forms: anadromous Sockeye and non-anadromous Kokanee Salmon (Burgner 1991). The two forms are generally sympatric throughout most of the geographic range, although many allopatric populations of Kokanee have been independently derived from Sockeye populations (Nelson 1968; Foote et al. 1989). In Canada, both forms are distributed throughout the Pacific drainage basin of British Columbia and the southwest corner of the Yukon Territory (Figure 1; Nelson 1968; Scott and Crossman 1973; Lee et al. 1980; Ford et al. 1995). With the exception of two known populations of Kokanee, the species does not occur naturally in either the Canadian Arctic or Hudson Bay drainages. These exceptions are Arctic and Thutade lakes which are head water lakes in the Peace River system (part of the Arctic drainage basin) (Figure 1; Nelson 1968; McPhail and Lindsey 1970; J. D. McPhail, Department of Zoology, University of British Columbia, Vancouver, personal communication 1999). These populations may have occurred in recent geological time as a result of a natural diversion of a water body from one drainage basin to another (Nelson 1968; Lindsey and McPhail 1986; McPhail and Lindsey 1986). Since 1990, Kokanee have been stocked in the Williston Lake area of the upper Peace River (Figure 1; S. Billings, British Columbia Ministry of Fisheries, Victoria, personal communication 1999; J. Burrows, British Columbia Ministry of Environment, Fort St. John, personal communication 1999).

We report here the first record of Kokanee (the non-anadromous form of Sockeye Salmon) in Great Slave Lake, Northwest Territories and present a possible explanation for the origin of the fish.

Field and Laboratory Observations

On 11 August 1991, a single specimen of a Pacific Salmon was caught in the commercial fishery on Great

Slave Lake near Hardesty Island (61°44'N, 114°37'W) (Figure 1). While the specimen was slightly decomposed when we obtained it, it was tentatively identified by external appearance using colouration and selected meristic character criteria described by Scott and Crossman (1973) as a Sockeye or Kokanee Salmon. The dorsal surface was a dark blue-gray; sides were silver-coloured; ventral surface was white; and no black spots were present on the body. Selected meristic characters were as follows: total gill raker count = 35 (22 lower, 13 upper); lateral line scales = 129; branchiostegal rays = 13; dorsal fin rays = 13; pelvic fin rays = 10; pectoral fin rays = 15; and anal fin rays = 14. We were not able to count pyloric caecae because they were badly decomposed. The fish measured 403 mm (fork length), weighed 701 g, was an immature female, and was aged from scales (6+ years; Figure 2) and an otolith (6+ years; see Figure 3a). The specimen (fish number 43202) is in the Arctic Fish Section fish collection at Fisheries and Oceans Canada (Freshwater Institute), Winnipeg.

Mosher (1972) suggested that Sockeye Salmon scale circuli and annuli laid down in freshwater were fine-textured while ocean circuli and annuli were wider and coarse-textured. As this fish's scale circuli and annuli were all fine textured and tightly spaced (Figure 2), the specimen was identified as a Kokanee (freshwater form of Sockeye Salmon).

Microchemistry of otoliths can provide details on the types of environments occupied during a fish's life (i.e., determination of life history type) (e.g., Halden et al. 1996). To confirm that this specimen was the freshwater form of the species, we used scanning proton microprobe analysis to measure and determine the pattern of strontium distribution in an otolith from the fish. Strontium was measured as sea water, on average, contains 8.0 mg/L strontium whereas freshwater contains only 0.1 mg/L (Rosenthal et al. 1970) and differences in strontium concentrations in fresh and sea water have

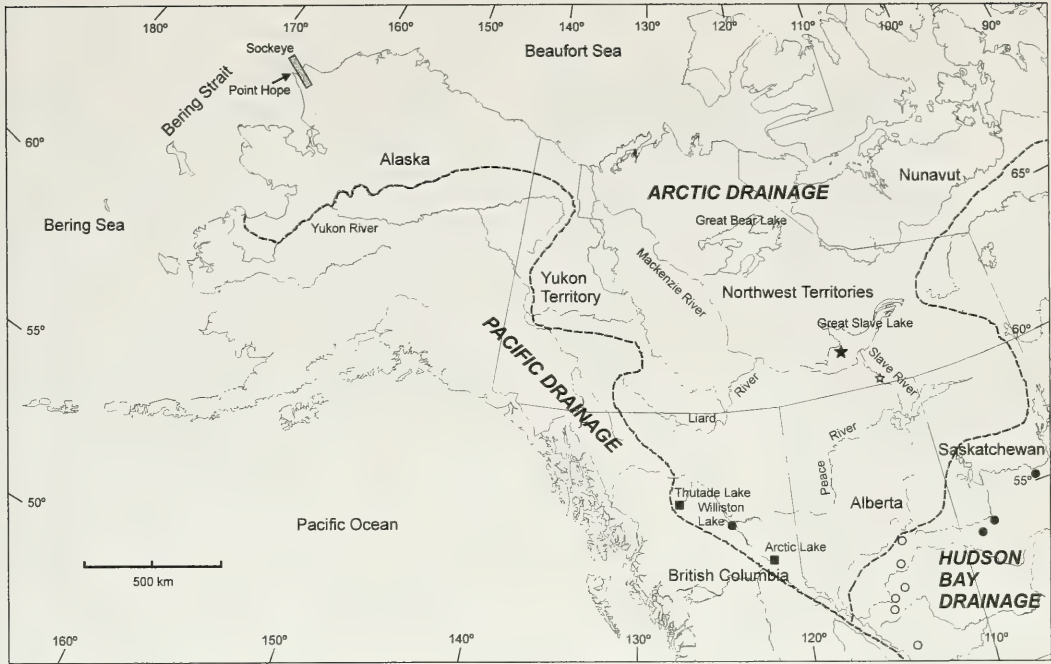


FIGURE 1. Map of northwestern North America showing generalized drainage areas (after Scott and Crossman 1973) and locations of Kokanee populations outside the Pacific drainage: location of new record for Kokanee (solid star); another recently reported specimen (open star); native populations (solid squares); introduced and current populations (dots); and previously introduced but currently extinct populations (open circles). Shaded bar represents northern limit of known spawning stocks of Sockeye Salmon.

been shown to be reflected in fish otolith composition (e.g., Radtke et al. 1988). The pattern of strontium distribution for this 6+ year old Salmon (Figure 3a) showed a low, relatively constant, “flat” profile from the core area (0 μm) to the outer edge of the otolith (ca. 1150 μm) indicating that the fish occupied an environment in which the strontium content was relatively low (i.e., freshwater) throughout its life. This strontium pattern was similar to those of known non-anadromous Arctic Char, *Salvelinus alpinus* (Babaluk et al. 1997). For comparison, Figure 3b shows a typical strontium profile from an otolith of a known anadromous Sockeye Salmon (caught in an estuary returning from the sea). The pattern of strontium distribution for this fish has a low region corresponding to the first two annuli (i.e., freshwater habitat) followed by a marked increase in strontium content (ca. 600 μm) corresponding to the 2nd annulus indicating that in its 3rd year the fish moved to an environment with a higher strontium content (i.e., the sea) and remained there until it was captured returning to freshwater to spawn.

Discussion

The capture of a Kokanee Salmon in Great Slave Lake represents a significant extension in the distri-

bution of the species (Figure 1). Spawning populations of anadromous Sockeye Salmon have been reported as far north as Point Hope, Alaska (Figure 1; Craig and Haldorson 1986) and although Sockeye Salmon are sporadically reported along Canada’s Arctic coast (Hunter 1974; Craig and Haldorson 1986; Babaluk et al. 2000), our specimen was not a stray from the marine environment (see Figures 2, 3). While Kokanee have, in the past, been stocked into lakes in Saskatchewan (Figure 1; Saskatchewan Department of Parks and Renewable Resources 1991), they were introduced only into lakes with no outflows and only into lakes in the Hudson Bay drainage (T. Housen, Saskatchewan Department of Environmental and Resource Management, La Ronge, personal communication 1999). In Alberta, the species was introduced into several lakes in the Hudson Bay drainage during the 1960s (Figure 1; Paetz and Nelson 1970) but according to Nelson and Paetz (1992), the species no longer exists in the province. In British Columbia, stocking records indicate that while Kokanee fingerlings (i.e., 0+ years old) were stocked in the upper Peace River system (i.e., Williston Lake area) during the 1990s, the practice did not commence until 1990 (S. Billings, personal communication, unpublished data 1999). As



FIGURE 2. Photomicrograph of a scale collected from the Kokanee Salmon captured in Great Slave Lake, 11 August 1991 showing annuli (numbered arrow heads).

our specimen was aged at 6+ years when captured in 1991 (i.e., hatched in 1985), it is highly unlikely to have originated from one of the provincial stocking programs. A more likely scenario is that it originated from the nearest known native Kokanee populations in Arctic or Thutade lakes, British Columbia at the headwaters of the Peace River (Figure 1).

Prior to construction of the W. A. C. Bennett (constructed between 1961–1980) and Peace Canyon (constructed between 1974–1980) dams, the Arctic and Thutade lakes Kokanee populations were isolated. With construction of the dams and the subsequent formation of Williston Lake (reservoir) suitable habitat was created for Kokanee (J. D. McPhail, personal communication 1999). Although Kokanee were stocked into the reservoir commencing in 1990, the species had already naturally appeared there (Ford et al. 1995; J. D. McPhail, personal communication 1999) likely from an out-migration from Arctic and Thutade lakes. While there would be high mortality rates of fish passing over spillways and through hydro-electric turbines, downstream migrations of salmonids, including Kokanee, in these ways frequently occur

(e.g., Stober et al. 1983). This phenomenon has also been noted in the case of W. A. C. Bennett and Peace Canyon dams (J. Burrows, personal communication 1999). As there are no other barriers on the Peace River, these entrained Kokanee have the potential to migrate down the river. A Pacific Salmon, reported as a Sockeye (Little et al. 1998), but most likely a Kokanee (A. Little, R. L. & L. Environmental Services Ltd., Edmonton, personal communication 1999) was caught in the Slave River in 1995 (see Figure 1). Although suitable spawning habitat may exist in downstream lakes (e.g., Lake Athabasca), spawning populations probably do not exist as no Kokanee have been previously reported from the commercial and domestic fisheries in these lakes.

One of the factors limiting the distribution of Pacific Salmon species (e.g., Kokanee) in Arctic and sub-Arctic areas is low water temperature (Craig 1989). However, significant temperature increases in these areas as a result of projected climate change (e.g., Watson et al. 1996) may result in increased presence of Kokanee in the area. If more frequent straying of Kokanee into or establishment of spawning populations in the Great Slave Lake area occurs, the impact on indigenous salmonids (e.g., Lake Whitefish, *Coregonus clupeaformis*, and Lake Trout, *Salvelinus namaycush*) may be significant.

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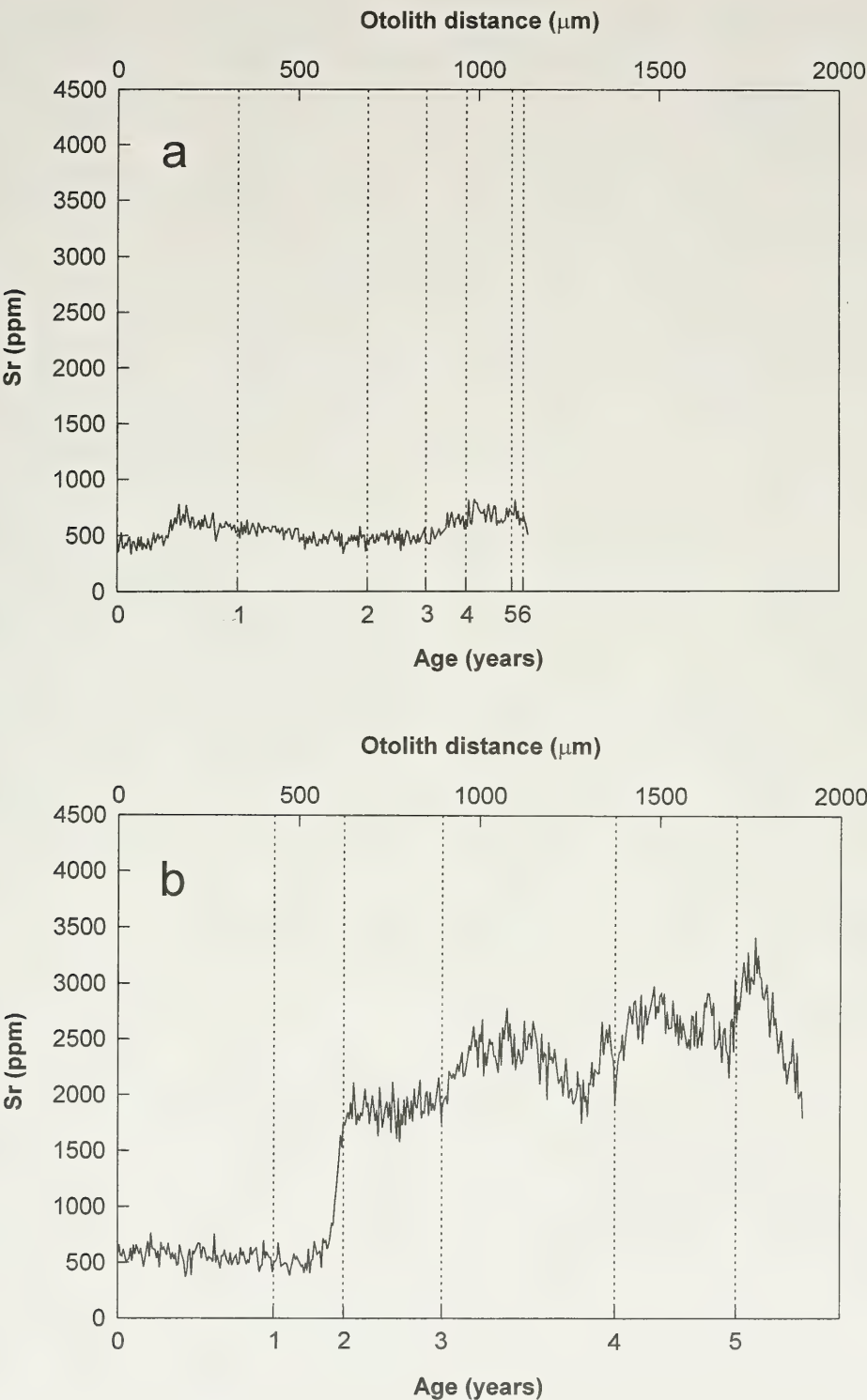


FIGURE 3. Strontium profile from a scanning proton microprobe line-scan of an otolith collected from (a) the Kokanee captured in Great Slave Lake, 11 August 1991 and (b) an anadromous Sockeye Salmon.

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Occurrence of Logperch, *Percina caprodes*, in Tributaries of Atikonak Lake, Labrador: A Northeast Range Extension in Canada.

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The Logperch (*Percina caprodes*), a species of restricted distribution in eastern Canada, is reported from tributaries of Atikonak Lake, a component of the Churchill River system, Labrador. In eastern Canada, this species has previously been recorded only from Québec river systems. Logperch collections in Labrador support the probability of a postglacial dispersal of freshwater fishes across Québec north of the Otish Mountains to the headwaters of the Churchill River system.

Key Words: Logperch, *Percina caprodes*, Percidae, range extension, Labrador, Canada.

The Logperch, *Percina caprodes* (Rafinesque), has a restricted distribution in eastern Canada. In eastern Canada, it has been previously reported only from Québec lakes and rivers that drain to James Bay, the St. Lawrence River, and the Gulf of St. Lawrence (Bergeron and Brousseau 1983). It has been suggested that the easternmost record of Logperch from the Aguanus River, Québec resulted from angler introductions of bait fish (Power 1965). However, Black et al. (1986) speculated, from post-glacial distributions of freshwater fish on the Québec-Labrador peninsula, that if the Aguanus River population occurs naturally then Logperch may still be present in Labrador. The present study documents the occurrence of Logperch from the Atikonak Lake watershed, a system that drains northeast to the Atlantic Ocean by means of the Churchill River and provides the first documented occurrence of a species from the family Percidae in Labrador waters.

Materials and Methods

Study Area

Atikonak Lake arises along the southern Québec-Labrador border and drains north to the Smallwood Reservoir, which in turn supplies the Churchill River, draining east to the Atlantic Ocean (Figure 1). In addition to Logperch, the Atikonak Lake system was found to contain Lake Whitefish (*Coregonus clupeaformis*), Round Whitefish (*Prosopium cylindraceum*), Brook Trout (*Salvelinus fontinalis*), Lake Trout (*Salvelinus namaycush*), Landlocked Atlantic Salmon (*Salmo salar*), Longnose Sucker (*Catostomus catostomus*), White Sucker (*Catostomus commersoni*), Lake Chub (*Couesius plumbeus*), Longnose Dace (*Rhinichthys cataractae*), Northern Pike (*Esox lucius*), Burbot

(*Lota lota*), Mottled Sculpin (*Cottus bairdi*), and Slimy Sculpin (*Cottus cognatus*).

Data Collection

Gillnet, trap net, minnow trap, and electrofishing surveys were conducted in August 1998 to determine the fish assemblage of the Atikonak Lake system. Methods and results pertaining to Logperch collections made by electrofishing are reported. Quantitative and qualitative electrofishing surveys were conducted from 11–22 August at twenty-one sites within sixteen tributary streams draining into Atikonak Lake (Figure 1). Electrofishing was conducted using a Smith-Root Model 12 electroshocker. Captured fish were killed (MS-222), measured for fork length (FL; ± 1 mm), preserved in 10% formalin, and later (i.e., within 30 days) transferred to 70% ethanol.

Site specific habitat surveys were conducted at all electrofishing sites. Habitat assessments consisted of measuring and estimating habitat characteristics for electrofished sections, all of which were >200 m². Habitat characteristics were assessed according to Scruton et al. (1992).

Results

Seven Logperch were collected at three of the qualitative electrofishing sites. One capture location was on Unnamed Tributary One (T-1; 52°34.63' N; 64°44.30' W), which drains into a bay in the southwest region of Atikonak Lake. The two remaining capture locations were on Unnamed Tributary Twelve (T-12; 52°30.48' N; 64°12.79' W) and Unnamed Tributary Thirteen (T-13; 52°27.42' N; 64°11.40' W), both of which drain into a large bay that forms the southeast extension of Atikonak Lake (Figure 1). There was a maximum linear distance, by water, of approximately 55 km between the capture locations (i.e., T-1 and T-13). Thus, more extensive sampling

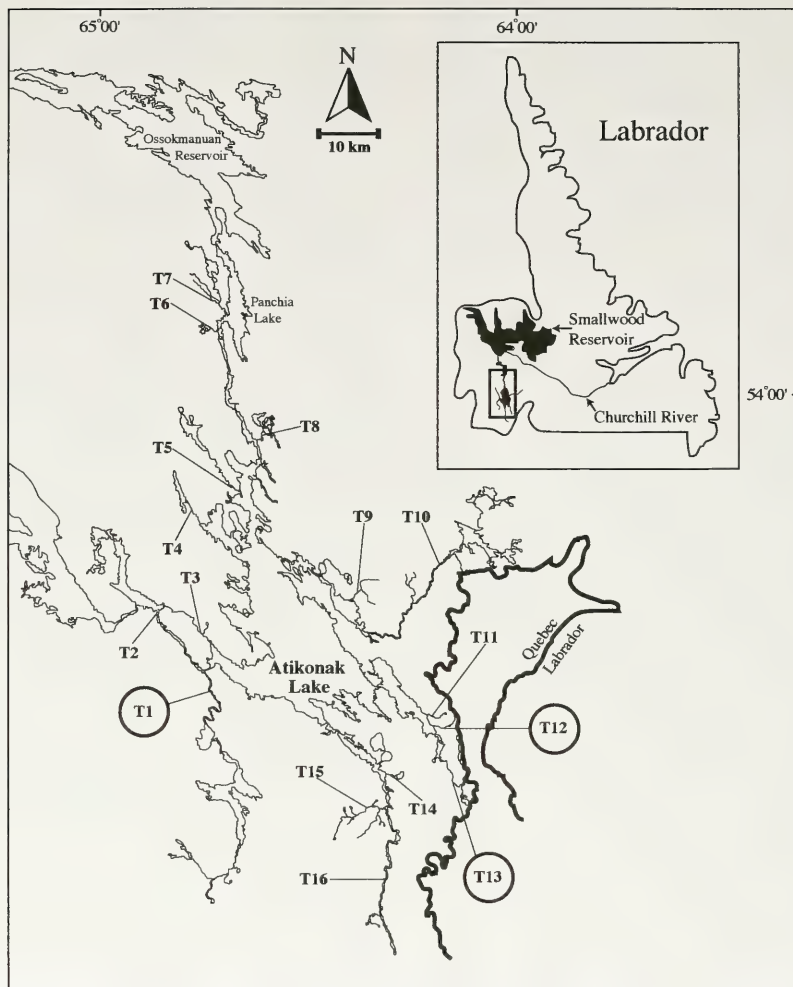


FIGURE 1. The location of tributaries (T1-T16) electrofished during a fish survey of the Atikonak Lake system, Labrador. Encircled tributaries indicate where Logperch were captured.

may reveal the presence of Logperch throughout the Atikonak Lake system and possibly in lakes and rivers downstream to the Smallwood Reservoir.

All seven Logperch were captured in relatively high flow, yet non-turbulent waters, over a predominantly cobble bottom in clear water at depths of 0.5 to 0.8 m and water temperatures of 13.8 to 18.6°C. Because fish may be attracted to the electrical field created during electrofishing and limited documentation on habitat use by Logperch in riverine environments, we provide a detailed habitat profile for each capture location.

Two Logperch, 70- and 76-mm FL, were collected on 14 August 1998 in T-1. The following fish were also caught at this site: thirty-eight Mottled

Sculpin, seventeen Longnose Sucker, two Brook Trout, two Burbot, and one White Sucker. The section of the stream sampled had a mean width of 48 m and the habitat was characterized as 80% riffle, 10% pool, and 10% run. The bottom was composed of a mixture of hard substrates; 50% small boulder (25 cm - 1 m diameter), 30% cobble (6 - 24 cm), 10% large boulder (>1 m), 5% gravel (2.0 - 5.0 cm), and 5% sand (0.006 - 2.0 cm). In-stream vegetation was minimal, covering approximately 2% of the bottom.

A single Logperch, 84-mm FL, was collected on 17 August 1998 in T-12. The following fish were also caught at this site: twenty-one Brook Trout, eighteen Mottled Sculpin, four Burbot, and three

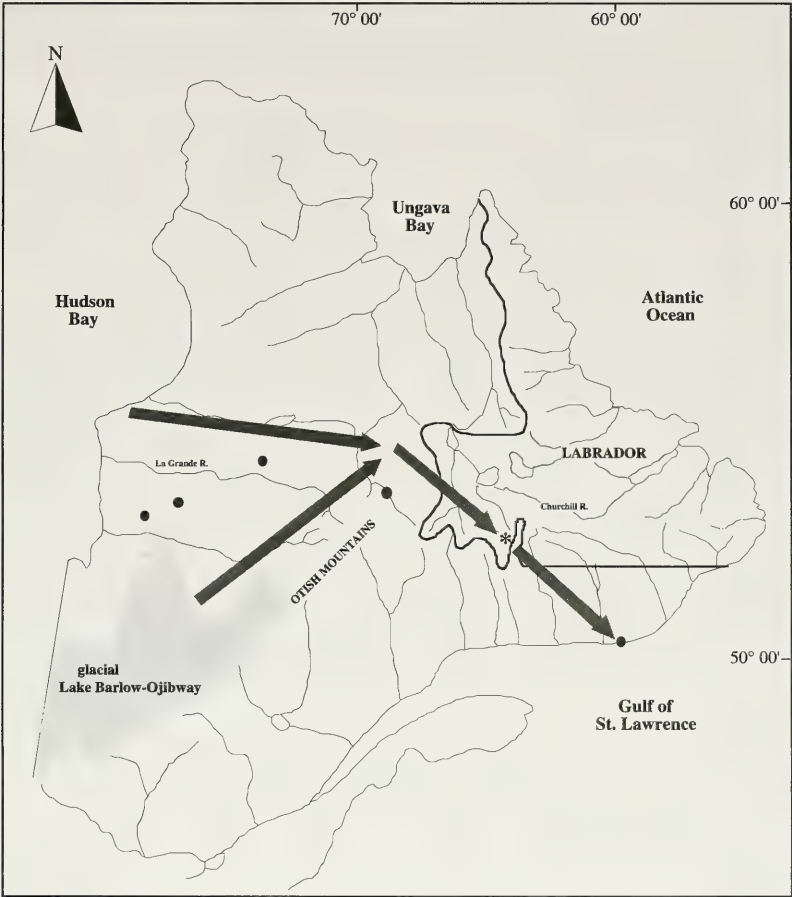


FIGURE 2. Map of the Québec-Labrador peninsula with arrows showing proposed overland dispersal routes followed by Logperch (adopted from Black et al. 1986). Logperch distribution records in Québec (●) and Atikonak Lake, Labrador (*) are indicated.

Round Whitefish. This stream was relatively narrow (3 m) throughout and the habitat sampled was characterized as 40% pool, 40% riffle, and 20% steady. The bottom was composed of a mixture of hard and soft substrates; 40% cobble, 20% small boulder, 20% gravel, 10% large boulder, 5% sand, and 5% mud (0.004 – 0.005 mm). There was no in-stream vegetation at this site.

Four Logperch, 74-, 80-, 80- and 90-mm FL, were collected on 17 August 1998 in T-13. The following fish were also caught at this site: thirty-two Round Whitefish, twenty-five Mottled Sculpin, seven Burbot, two Northern Pike, one Longnose Dace, and one White Sucker. Of the three capture locations, this stream section was intermediate in width (10.5 m). The habitat sampled was characterized as 60% pool, 20% riffle, and 20% steady. The bottom was composed of a mixture of hard and soft substrates; 40% cobble, 30% small boulder, 10% large boulder,

10% mud, 5% gravel, and 5% sand. In-stream vegetation covered approximately 10% of the bottom.

Discussion

Six Logperch collected by Power (1965) in the Aguanus River, Québec (50°10' N, 62°05' W) represent the easternmost distribution of this species in Canada. Power (1965) suggested that this extreme eastern distribution did not occur naturally, but was the result of discarding of bait fish by anglers. Black et al. (1986) summarized the distribution and probable post-Pleistocene glacial dispersion of freshwater fishes in Labrador suggesting a transfer route from the Mississippi refuge through the Great Lakes basin to glacial Lake Barlow-Ojibway and finally, across Québec north of the Otish Mountains to headwaters of the Churchill River, Labrador. Black et al. (1986) criticized earlier proposed postglacial dispersal routes on the Québec-Labrador peninsula (Legendre and

Legendre 1984), as they were based on inaccurate distributional maps for many of the fishes in Labrador. In their discussion of postglacial dispersal routes of freshwater fishes, Black et al. (1986) speculated that if Logperch occur naturally in the Aguanus River they may still be present in some areas of Labrador. When our records of Logperch from Atikonak Lake are added to the Logperch distribution map documented for the Québec-Labrador peninsula (Bergeron and Brousseau 1983), the result is a distinct arch that extends overland across Québec, passing through the southwest corner of Labrador before reaching the Aguanus River (Figure 2). This arch follows one of the proposed postglacial dispersal routes followed by freshwater fishes presented by Black et al. (1986), suggesting that the Logperch collected on the Québec-Labrador peninsula occur naturally.

The specimens of *P. caprodes* collected in tributaries of Atikonak Lake are catalogued in the Royal Ontario Museum as collection ROM 71821 and in the Canadian Museum of Nature as CMNFI 1999-0001 and CMNFI 1999-0002.

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Notes

Acadian Flycatcher, *Empidonax virescens*, Nest Site Characteristics at the Northern Edge of its Range

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Information on breeding habitat requirements for the Acadian Flycatcher (*Empidonax virescens*) is scarce but important for managing remnant woodlots for this species considered endangered in Ontario. In 1998, we examined nest site characteristics for 11 Acadian Flycatcher nests in southwestern Ontario. Nests were most often placed in trees of diameter at breast height (DBH) class 7.5 cm–15 cm ($n = 6$, 54.5%) followed by saplings (DBH < 7.5 cm) ($n = 4$, 36.4%), and one nest was placed in a tree of DBH class 22.5 cm–37.5 cm (9.0%). Overstory canopy height and sub-canopy height averaged 23.0 ± 2.3 m and 4.7 ± 3.8 m, respectively. The majority of the nest sites had a high percent canopy cover ($95.0 \pm 5.0\%$) and a low percent ground cover ($42.7 \pm 28.0\%$). Percent understory vegetation cover at four height intervals were uniformly below 50% and the highest total basal area was for trees of a DBH between 22.5 cm and 37.5 cm. Maintaining canopy cover in riparian areas may be an important component in promoting Acadian Flycatcher recovery.

Key Words: Acadian Flycatcher, *Empidonax virescens*, Carolinian forest, endangered species, forest management, habitat, nest site, Ontario.

The Acadian Flycatcher (*Empidonax virescens*) is a small forest-interior neotropical migrant and was designated as Endangered in 1994 by the Committee on the Status of Endangered Wildlife in Canada. Its breeding range in Canada is highly restricted to the most southwestern part of Ontario within the Carolinian Forest Zone. During the 19th Century, the Carolinian forest cover was largely cleared for agricultural and industrial purposes. Current regional forest cover of the Carolinian Forest Zone is estimated between 3 and 22% of the total area (Riley and Mohr 1994*). Not including a few larger protected woodlands where breeding Acadian Flycatchers have traditionally been recorded, the remaining breeding habitat for this species is restricted to small, isolated woodlots many of which are subject to selective logging on a regular basis. An analysis of Acadian Flycatcher nest sites therefore represents an important first step towards management of the habitat and a better understanding of the species' breeding ecology. This study is the first to provide a quantitative description of the nesting habitat for breeding Acadian Flycatchers at the northern limit of the species' range.

Study area

We studied in two wooded ravines (Elgin 42°35'N, 81°15'W, and Kent 42°30'N, 81°45'W, counties) and seven tableland woods (Haldimand-Norfolk County

42°30'N, 80°20'W) of Canada's Carolinian forest zone in southwestern Ontario. The Elgin County site lies on a western extension of the Norfolk Sand Plain, a rolling tableland deeply incised (12–15 m) by one narrow creek and three main tributaries. The dominant tree cover on this 142 ha site is Sugar Maple (*Acer saccharum*) and American Beech (*Fagus grandifolia*). The woodlot in Kent County is a 44 ha wooded ravine located on an extension of St. Clair Flats Clay Plain dominated by Sugar Maple, American Beech, and Black Maple (*Acer nigrum*). The Haldimand-Norfolk area is situated along the north shore of Lake Erie and comprises an area of 291 ha mainly occupied by agricultural lands with interspersed woodlots. These tableland woods contained tree species such as Sugar Maple, American Beech, White Oak (*Quercus alba*), Red Oak (*Q. rubra*), Tuliptree (*Liriodendron tulipifera*), cherry (*Prunus* spp.), Sassafras (*Sassafras albidum*), Eastern Hemlock (*Tsuga canadensis*), and plantations of Red Pine (*Pinus resinosa*) and Eastern White Pine (*P. strobus*).

Materials and Methods

From late May to late June 1998, we surveyed each woodlot for singing Acadian Flycatcher males. We identified a territory as an area in which a male was heard singing more than once. When a territory was identified, we conducted extensive searches for

TABLE 1. Nest site characteristics for Acadian Flycatcher nest sites ($n = 11$) in southwestern Ontario, 1998.

Habitat Variables	\bar{x}	SD	Range
Number of trees per hectare	629.5	115.0	475–800
Shannon-Wiener index	1.6	0.2	1.2–1.9
Canopy cover (%)	95.0	5.0	85–100
Ground cover (%)	42.7	28.0	5–100
Canopy height (m)	23.0	2.3	19.2–24.9
Sub-canopy height (m)	4.7	3.8	0.0–10.2
Vegetation profile (%)			
Cover at 0–0.3 m (C1)	47.5	23.4	0.0–75.0
Cover at 0.3–1 m (C2)	30.8	25.3	0.0–71.0
Cover at 1–2 m (C3)	31.7	22.5	5.5–76.0
Cover at 2–3 m (C4)	34.2	25.1	0.0–76.5
Basal area (m^2/ha)			
Trees of 7.5 cm < DBH < 15 cm (BASAL1)	3.5	1.4	0.75–5.5
Trees of 15 cm < DBH < 22.5 cm (BASAL2)	3.7	1.8	0.75–6.75
Trees of 22.5 cm < DBH < 37.5 cm (BASAL3)	8.6	6.0	1.75–21.0
Trees of 37.5 cm < DBH < 52.5 cm (BASAL4)	7.3	4.7	0.0–16.0
Trees of DBH \geq 52.5 cm (BASAL5)	7.9	9.7	0.0–30.2
Nest height (m)	2.6	1.7	1.34–6.5
Distance from nest to nearest stream (m) ($n = 7$)	4.1	3.3	0.0–8.0

females or nests three times for each territory. Because Acadian Flycatchers are known to double brood (Wilson and Cooper 1998), after what we assumed to be the first nesting attempt, we searched for second nests within the given territory.

At the end of the breeding season, we sampled 17 habitat variables (Table 1) within a 0.04-ha (11.28-m radius) circular sampling area around each nest. We recorded canopy cover, ground cover, overstory canopy height, sub-canopy height (top canopy of understory trees that were not part of the overstory), tree basal area for five diameter at breast height (DBH) classes, vegetation profile, number of trees with a DBH 7.5 cm for each species (James and Shugart 1970), distance from the nest to the nearest stream, and nest height. Vegetation profile was sampled using a 3-m vegetation profile board (Nudds 1977; Noon 1981) and the percentage cover was estimated at four height intervals (0–0.3 m, 0.3–1 m, 1–2 m, and 2–3 m). We took readings from the board held at 11.28 m from the nest in each cardinal direction. We used the proportion of trees within each species to calculate the Shannon-Wiener diversity index (Barbour et al. 1987: 164). We recorded the DBH of nest tree and tree species used to support the nest.

Results

We located and sampled 11 Acadian flycatcher nest sites (9 first nestings) in two wooded ravines. Seven nests were placed in American Beech (63.6%), two in Sugar Maple (18.2%), and two in hawthorns (*Crataegus* spp.) (18.2%). Nests were most often placed in trees of DBH class 7.5 cm–15 cm ($n = 6$, 54.5%) followed by saplings (DBH < 7.5 cm) ($n = 4$, 36.4%), and one nest was placed in a tree of DBH class 22.5 cm–37.5 cm (9.0%). All nests

were placed on low branches at a mean distance of 4.1 ± 3.3 m ($n = 7$) from a stream, at an average height of 2.6 ± 1.7 m. Nest sites had a high overstory canopy height compared to the low sub-canopy height and in some sites, sub-canopy was absent all together (Table 1). The majority of the nest sites had a high percent canopy cover and a low percent ground cover (Table 1). Percent cover at the four height intervals was uniformly below 50% and the highest total basal area was for trees of DBH between 22.5 cm and 37.5 cm, followed by trees of DBH 52.5 cm, and of DBH between 37.5 cm and 52.5 cm, all DBH classes representing larger trees.

Discussion

Acadian Flycatchers occupied breeding sites within tall even-aged wooded ravines characterized by very low or absent understory vegetation and a heavy overstory canopy cover. The nests were placed in trees with a small DBH and on average 3 m above the ground near a stream.

Quantitative accounts of nest site characteristics for Acadian Flycatchers are primarily limited to nest tree species and nest height (Bent 1963; Mumford 1964; Walkinshaw 1966; Wilson and Cooper 1998). Our mean nest height (2.6 ± 1.7 m) was significantly lower than the means of both Michigan ($\bar{x} = 4.0$ m, $n = 37$, $t_{10} = 4.96$, $P = 0.001$) and Arkansas nests ($\bar{x} = 6.5$ m, $n = 511$, $t_{10} = 4.91$, $P = 0.001$) (Mumford 1964; Wilson and Cooper 1998) most likely as a result of our smaller sample size. Mumford (1964), through detailed observations of the species' productivity in Michigan, noted that although nests were most often placed in Witch Hazel (*Hamamelis virginiana*), a wide variety of trees were used to support the nest. In a similar study in Michigan, out of 140

nests, most ($n = 63$) was placed in American Beech (Walkinshaw 1966). In Arkansas, Acadian Flycatchers appeared to avoid certain tree species within the territory (e.g., Green Ash, *Fraxinus pennsylvanica*) and favored other species (e.g., Sugarberry, *Celtis laevigata*) not in relation to their availability. However, reproductive success was not related to tree species used and Acadian Flycatchers thus appeared to select nesting trees based on their structure (Wilson and Cooper 1998). Our results are consistent with the latter observations. Although American Beech was the most frequently used nesting tree, Acadian Flycatchers used trees close to a stream, with low sloping branches on which they would build their nest. Walkinshaw (1966) and Wilson and Cooper (1998) also report that nests were consistently placed at the end of a branch over an opening such as shaded trails, sloughs, or streams. The association of Acadian Flycatcher nests with streams is poorly understood.

The use of woodlots in Ontario with a heavy overstory canopy by breeding Acadian Flycatchers is similar for nests in Arkansas (Wilson and Cooper 1998) where canopy cover measured directly above the nest was high (94%). Perhaps proximate factors, such as insect abundance or microclimate, are influenced by a heavy overstory canopy. This appears to be an important structural characteristic to consider when managing woodlots used by Acadian Flycatchers, as increased logging will likely contribute to the thinning of the overstory canopy.

Detailed species-specific studies on nesting habitat requirements as reported here are essential for proper forest management. Many species sharing a nesting woodlot select for different habitat characteristics, and an effective logging prescription must include a combination of all requirements. For example Hooded Warblers (*Wilsonia citrina*) and Acadian Flycatchers frequently use the same nesting woodlots but Hooded Warblers require dense understory vegetation (Kilgo et al. 1996; Bisson and Stutchbury), whereas our study shows that Acadian Flycatchers chose sites with relatively no ground cover. Our study represents the first step in identifying habitat characteristics used by nesting Acadian Flycatchers in Canada and provides a good baseline for further ecological studies assisting the conservation of this species.

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Recent Reports of Grizzly Bears, *Ursus arctos*, in Northern Manitoba

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I evaluate three reports of sightings of Grizzly Bears (*Ursus arctos*) from 1990 to 1998 in northeastern Manitoba. These observations indicate that Grizzly Bears may be extending their range to the southeast into Manitoba, a province from which they were thought to have been extirpated.

Key Words: Grizzly Bear, *Ursus arctos*, Wapusk National Park, Hudson Bay Lowlands, Manitoba.

The Grizzly Bear (*Ursus arctos*) has been considered extirpated from Manitoba, though they formerly ranged throughout the prairies in the southwest quarter of the province (Banci 1991*). The last unconfirmed sighting was made in the Duck Mountains in 1923 (Sutton 1967). I summarize and evaluate recent sightings of Grizzly Bears in northeastern Manitoba.

On 27 July 1990, A. Didiuk, Canadian Wildlife Service, observed and photographed a Grizzly Bear from a fixed-wing aircraft approximately 1 km inland from the Hudson Bay coast between Hubbart Point and Nunalla (Figure 1), at 59° 34' N, 94° 52' W (Roberts 1997*). Didiuk was familiar with the diagnostic features of bears, and confirmed the presence of the shoulder hump and a concave facial profile typical of Grizzly Bears. A Grizzly Bear was apparently seen in that area that year by local

hunters, and an experienced local trapper saw its tracks (J. Batstone, personal communication).

On 15 June 1996, D. Humburg, Missouri Department of Conservation, reported sighting and photographing a Grizzly Bear from a fixed-wing aircraft 6.5 km from the coast, near Thompson Point, in Wapusk National Park (Figure 1) at 58° 14' N, 93° 04' W (Roberts 1997*). The photographs show a shoulder hump and concave facial profile. Humburg was also familiar with Grizzly Bears, having seen them before in other areas.

On 5 June 1998, I observed a Grizzly Bear from a helicopter moving along a coastal beach ridge near Thompson Point in Wapusk National Park (Figure 1) at 58° 20' N, 93° 02' W. The diagnostic features of the shoulder hump and concave facial profile were clearly visible. The bear appeared to be mature and in

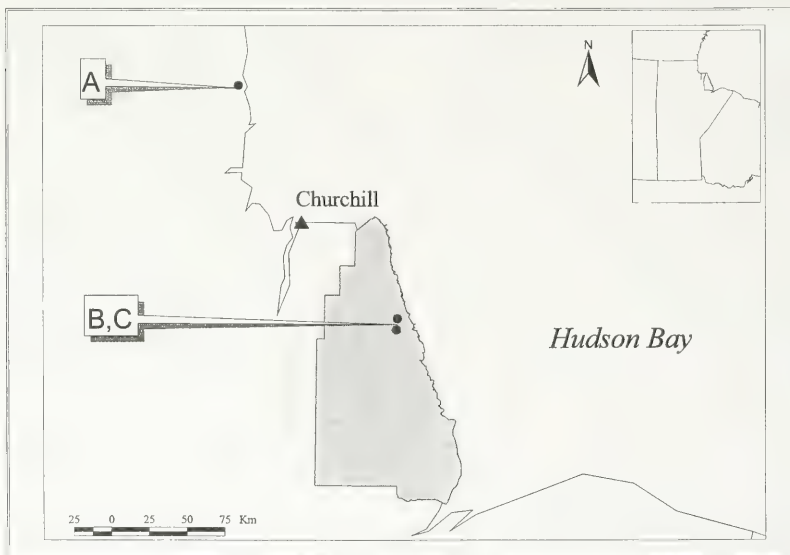


FIGURE 1. Map of northeastern Manitoba showing locations of Grizzly Bear observations: (a) 27 July 1990, (b) 15 June 1996, (c) 5 June 1998. Shaded area indicates Wapusk National Park. Inset map shows the location of the park within Manitoba.

good condition. Tracks found in mud in the vicinity the next day were examined and imprints of the characteristically long claws were clearly visible; much longer than the claw imprints of a Polar Bear (*Ursus maritimus*) or Black Bear (*Ursus americanus*), which also inhabit the area. The toe imprints in these tracks were joined, and did not arc, both of which characteristics are indicative of Grizzly Bear, rather than Black Bear tracks (Herrero 1985). The bear was not seen again despite an intensive search of the area on subsequent days.

These three reports meet the highest rating in the criteria developed by Almack (1986*) for evaluating reports of Grizzly Bears. All sightings were made by experienced observers and photographs were taken. At least two criteria distinguishing grizzlies from Black Bears were noted in each case; a prominent shoulder hump, concave facial profile or long claws. Black Bears in Manitoba can exhibit variable coat colour, including brown and blonde, though such colour phases are generally rare in the northern part of the province (W. Roberts, personal communication), so colour cannot be considered an identifying criterion.

All of these sightings were made in the Hudson Bay Lowlands Ecozone, outside any of the ecozones which Banci (1991*) identified were important to Grizzly Bears. It is unclear whether or not the habitat is of sufficiently high quality to support Grizzly Bears year-round in the Hudson Bay Lowlands. South of the Seal River, midway between the observation sites, there are no Arctic Ground Squirrels (*Spermophilus parryii*) which are generally felt to be important to Grizzly Bears in other Arctic areas (Nagy et al. 1983). Further, the Wapusk National Park area has very low berry productivity, and other plants which are considered to have high value for Grizzly Bears elsewhere in their range, such as Sweet Vetch (*Hedysarum* sp.) are sparse (Clark 1996). The tracks observed in 1998 proceeded in a straight line towards a Canada Goose (*Branta canadensis*) nest containing eggs, then veered away, possibly because of the helicopter. In spring, the area where this and the 1996 observation were made contains a high number of nesting Canada Geese and Lesser Snow Geese (*Chen caerulescens*). Grizzlies are known to eat goose eggs, goslings and moulting flightless geese. Also, the Cape Churchill Caribou (*Rangifer tarandus*) herd calves in the area, providing another potential food source.

Since there is no known source population of Grizzly Bears to the south or west of these sightings, which is bordered to the east by Hudson Bay, it is most likely that the bear or bears observed had travelled south from resident populations in the Northwest Territories. Barren-ground Grizzly Bears have large home ranges and move long distances, particularly in the spring and summer. P. McLoughlin

(personal communication). found that the mean annual range of adult male Grizzly Bears in the central Northwest Territories is 6685 km², and that they may move up to 12 km per day in the spring. Taylor (1995) observed an adult male Grizzly Bear on sea ice over 500 km from any known source population. Such ranges and movements are consistent with the distance between known Grizzly Bear populations and the location of the recent observations in Manitoba.

Elders of the York Factory First Nation indicated that they had no knowledge of Grizzly Bears in the area (Flora Beardy, personal communication), which they have inhabited for over 300 years. However, both they and elders from the Fox Lake First Nation have Cree names for the Grizzly Bear and distinguish it from Black and Polar bears, suggesting an awareness of this species. Preble (1902) mentioned that Grizzly Bears were not known from the area around Churchill; only from the barren lands to the northwest, and they were, at most, rare. It is not clear if these three sightings indicate a possible trend toward an extension of their range from the Northwest Territories into northeastern Manitoba. Grizzly Bears were thought to have increased their range southeastward in the mainland Northwest Territories during the 20th century (Banfield 1959; Harington et al. 1962). However since the mid-1960s there have been many surveys in the area where these sightings were made and it is likely that if significant numbers exist they would have been observed. Conclusions about the population status of Grizzly Bears in Manitoba cannot be drawn from these recent observations. However it is important to document these observations since there have been so few records of Grizzly Bears in northern Manitoba, and it is possible the population to the north may be in the process of extending its range.

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Effect of a Water-Level Increase on Use by Birds of a Lakeshore Fen in Québec

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We monitored the use by birds of a fen located on the shores of Lake Sainte-Anne, in Kamouraska County, Québec, prior to (1984) and following impoundment (1987) and subsequent increase in water level. One of four species of waterbirds (Black Duck) increased from 1984 to 1987, and eight new species were recorded. Four of seven species of high-nesting passerines increased (Common Grackle, Eastern Kingbird, Red-winged Blackbird, Tree Swallow), but two of three species of low-nesting passerines declined (Savannah Sparrow and Swamp Sparrow). Overall, bird density declined, richness increased, but diversity remained unchanged following the water-level increase. Our data illustrates that the responses of birds to water-level management depends on their life history, and suggests that managers should *a priori* consider species not targeted by the management, especially if rare or endangered species are present.

Key Words: birds, density, diversity, habitat, management, waterfowl, water level, Québec.

Water level is an important factor influencing habitat suitability for waterfowl (Weller 1990). Fluctuating water levels can reduce nest-site availability (Laperle 1974), reproductive success (Jobin and Picman 1997), and food availability (Swanson and Meyer 1977). However, properly managed water-level fluctuations enhance wetlands by increasing macroinvertebrate abundance (Kaminski and Prince 1981) and by facilitating reestablishment of emergent vegetation (Merendino et al. 1990). Although water-level management typically benefits waterfowl (Schroeder et al. 1976), the impact of water-level management on other bird species is sel-

dom considered. Our goal was to assess the impact of a water-level increase in a fen on use by waterfowl and birds not targeted by the management.

The study was conducted on the shores on Lake Sainte-Anne (47°12' N, 69°48' W), ca. 55 km south of Saint-Jean-Port-Joli, in Kamouraska County, Québec. Surrounding vegetation types are dominated by Black Spruce (*Picea mariana*), Balsam Fir (*Abies balsamea*), and Trembling Aspen (*Populus tremuloides*).

Around 1900, a dam was built at the mouth of Jaune River, the outlet of Lake Sainte-Anne, for wood-floating purposes. Subsequent deterioration of the structure in the 1960s resulted in a 1-meter drop in water level. As the water-level of surrounding wetlands decreased, overall use of the lake by dab-

*See Documents Cited section.

bling ducks declined (Laniel and St-Georges 1986*). In August 1984, Ducks Unlimited Canada and the government of Québec constructed a new dam equipped with water control structure.

Prior to flooding in 1984, stands of Leather Leaf (*Cassandra calyculata*), Sweet Gale (*Myrica gale*), Three-way Sedge (*Dulichium arundinaceum*), and mosses (*Sphagnum* spp.) characterized the lakeshore vegetation of Lake Sainte-Anne. Dense stands of Bulrush (*Scirpus cyperinus*) and Three-way Sedge occurred at the mouth of the Jaune River. The western shore was sparsely vegetated with Cattail (*Typha latifolia*), Bulrush, and Rough Alder (*Alnus rugosa*). Dead trees were common around the lake (Laniel and St-Georges 1986*). In 1985, beds of Sweet Gale and *Sphagnum* were now floating (Laniel and St-Georges 1986*, 1987*). Post-flooding, water level increased by 90 cm, and overall area of Lake Sainte-Anne increased from 4.01 km² to 5.76 km².

Bird communities were sampled in the spring of 1984 (pre-flooding) and three years later in the spring of 1987 (post-flooding), using the methods described by Burnham et al. (1980). Four transects totalling 1600 m (550, 500, 250, and 300 m) were established parallel to the shoreline and marked with metal stakes. Observers walking the transect lines identified bird species present within 45 m, and estimated their distance to the nearest 5 m from the transect line (Burnham et al. 1980). The same transects were used in 1987.

Transects were surveyed in early morning, beginning around 08:00 h. Ten surveys were conducted during both years, between 29 May and 29 June 1984, and from 2 to 18 June 1987. Surveys were conducted at 1-3 day intervals. Data were pooled across transects to assess overall changes in bird communities. Bird

densities were calculated using the software package TRANSECT (Burnham et al. 1980). Conformity of the density data with Fourier Series was verified with the chi-square test, using a rejection level of $P = 0.05$ (Sokal and Rohlf 1981: 701-724). This was necessary to meet the assumption of an increased detectability of individuals as they approach transect lines (Burnham et al. 1980). Consequently, one survey for each sampling year was rejected for the calculation of densities (Burnham et al. 1980).

Bird species diversity was calculated for all transects using the Shannon-Weaver equation (Shannon and Weaver 1963). We used non-parametric statistics (Mann-Whitney U-tests) to compare mean bird diversity, mean densities, and mean number of birds seen per transect between years. Rejection levels were set at $\alpha = 0.05$ and corrected for multiple tests using Bonferonni's correction.

Twenty-eight species of birds were observed around Lake Sainte-Anne. The number of species increased from 19 in 1984 to 23 in 1987, and 14 species were observed during both years (Table 1).

Effects of flooding differed for waterbirds, high nesters (i.e., species nesting >2 m above-ground), and low nesters (i.e., birds nesting on the ground or in low shrubs). Among waterbirds, mean number of birds seen per survey increased significantly only for Black Duck (Table 1). However, eight species were recorded only after flooding: Pied-Billed Grebe (*Podilymbus podiceps*), American Bittern (*Botaurus lentiginosus*), Wood Duck (*Aix sponsa*), Blue-winged Teal (*Anas discors*), Green-winged Teal (*Anas crecca*), Virginia Rail (*Rallus limicola*), Sora (*Porzana carolina*), and Belted Kingfisher (*Ceryle alcyon*).

Post-flooding, four of seven species of high-nesting passerines increased (Common Grackle, Eastern

TABLE 1. Pre- (1984) and post-management (1987) mean numbers of birds seen per survey on the Lake Sainte-Anne fen, Kamouraska County, Québec.

Species	1984	1987	P
WATERBIRDS			
American Black Duck (<i>Anas rubripes</i>)	0.1	3.3	<0.0001 *
Ring-necked Duck (<i>Aythya collaris</i>)	0.5	0.7	0.72
Spotted Sandpiper (<i>Actitis macularia</i>)	0.2	0.3	0.66
Common Snipe (<i>Gallinago gallinago</i>)	1.6	1.2	0.50
HIGH-NESTING PASSERINES			
Alder Flycatcher (<i>Empidonax alnorum</i>)	0.1	0.1	0.97
Eastern Kingbird (<i>Tyrannus tyrannus</i>)	0.3	2.3	<0.01 *
Tree Swallow (<i>Tachycineta bicolor</i>)	0.8	7.2	<0.001 *
Barn Swallow (<i>Hirundo rustica</i>)	0.3	0.1	0.99
European Starling (<i>Sturnus vulgaris</i>)	0.2	0.2	0.97
Red-winged Blackbird (<i>Agelaius phoeniceus</i>)	16.9	34.3	<0.0001 *
Common Grackle (<i>Quiscalus quiscula</i>)	0.7	6.0	<0.0001 *
LOW-NESTING PASSERINES			
Savannah Sparrow (<i>Passerculus sandwichensis</i>)	3.2	0.1	<0.001 *
Swamp Sparrow (<i>Melospiza georgiana</i>)	17.7	2.7	<0.0001 *
Bobolink (<i>Dolichonyx oryzivorus</i>)	4.2	1.6	0.03

*indicates significant differences following Bonferonni's correction.

Kingbird, Red-winged Blackbird, and Tree Swallow; see Table 1). The Red-winged Blackbird was the most abundant species of high-nesting passerine during both years (Table 1). Among high-nesters, only one species was not recorded post-flooding (American Robin, *Turdus migratorius*).

Low-nesting passerines were generally less abundant, and two of three species decreased significantly in 1987 (Savannah Sparrow, Swamp Sparrow; see Table 1). Moreover, four species recorded prior to flooding were not observed post-flooding: Common Yellowthroat (*Geothlypis trichas*), Wilson's Warbler (*Wilsonia pusilla*), Song Sparrow (*Melospiza melodia*), and Lincoln's Sparrow (*Melospiza lincolni*). Alternately, one low-nesting species was only recorded post-flooding (Killdeer, *Charadrius vociferus*).

Overall mean bird density declined ($Z = -2.21$, $P = 0.03$) from 5.77 birds/ha (SD = 1.47) in 1984 to 4.24 birds/ha (SD = 1.21) in 1987. However, mean species richness increased from 9.3 (SD = 2.8) in 1984 to 11.9 (SD = 1.8) in 1987 ($Z = -2.16$, $P = 0.03$), whereas mean diversity index for Lake Sainte-Anne remained unchanged at 0.73 for both 1984 (SD = 0.11) and 1987 (SD = 0.07).

Water-level manipulation is a common technique used to enhance quality of wetland habitats for waterfowl (Weller 1978; Bishop et al. 1979; Merendino et al. 1990). Impoundment of the Lake Sainte-Anne fen and the associated rise in water level increased its use by Black Ducks, and eight new species of waterbirds were recorded, suggesting that the effects were positive for this avian group. However, the response of passerines was a function of their nesting preferences. High-nesting species were recorded more often in 1987 compared to 1984, and the opposite trend was observed for low nesters. The habitat available for species nesting close to the ground, and using low bushes or dry land for foraging was undoubtedly restricted to a narrower strip between the open water and the forest following the impoundment, and this likely explains the lower numbers of birds observed. Alternately, species nesting in trees or cavities (Tree Swallow, Kingbird, and Common Grackle) or in emergent vegetation (Red-winged Blackbird) likely benefited from the flooding. Nesting and foraging habitats of many high-nesters were probably enhanced by greater water-vegetation interspersions (e.g., Jobin and Picman 1997). Finally, the high abundance of Red-winged Blackbirds probably buffered an increase in diversity following an increase in species richness.

The increase in water level on Lake Sainte-Anne in Québec increased its use by aquatic birds, so the primary goal of the management plan was achieved. Similarly, high-nesting birds benefited from water-level management. However, some bird species declined, especially low-nesting passerines. We suggest that managers thoroughly consider the ecology of birds present before water-level management is implemented.

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Coyote, *Canis latrans*, Use of Commercial Sunflower, *Helianthus* spp., Seeds as a Food Source in Western Kansas

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Food habits of Coyotes (*Canis latrans*) were determined by analysis of scats collected in western Kansas in 1996. Mammals were the most frequently occurring food of Coyotes (100% of scats), followed by plants (39%), insects (30%) and birds (9%). Commercial sunflower (*Helianthus* spp.) seeds were found in 9 of 23 scats. When present, they composed a high volume of individual scats (\bar{x} = 31%). Substantial use of commercial sunflower seeds as a food source by Coyotes has not been previously documented.

Key Words: *Canis latrans*, Coyote, food habits, sunflower seeds, western Kansas.

Food-habit studies of Coyotes (*Canis latrans*) in the Great Plains region (e.g., Fichter et al. 1955; Gier 1968; Springer and Smith 1981; Gese et al. 1988a; Brillhart and Kaufman 1994, 1995; Lewis et al. 1994) have demonstrated that Coyotes are opportunistic predators, responding to available food sources. In recent years, commercial sunflower (*Helianthus* spp.) crops have increased greatly throughout this region; between 1990–1996, land planted to sunflower crops (oil and non-oil use combined) in Kansas increased from 30 352 ha to 115 336 ha (National Agricultural Statistics Service 1999). Use of commercial sunflower seeds as an appreciable food source previously has not been documented for Coyotes. However, use of commercial sunflower seeds as food has been documented for other carnivores including American Badger (*Taxidea taxus*; Sovada et al. 1999), Red Fox (*Vulpes vulpes*; Sargeant et al. 1986), Raccoon (*Procyon lotor*; Greenwood 1981), Striped Skunk (*Mephitis mephitis*; Greenwood 1999), and Swift Fox (*Vulpes velox*; Sovada et al. 2001). Sunflower seed protein and fat content average 6 g and 14 g per 28 g, respectively (National Sunflower Association 1989), providing a potentially high quality food source.

Study Area and Methods

We collected Coyote scats on a 518-km² study area (39°10'N, 101°13'W) encompassing southern Sherman and northern Wallace counties in western Kansas in 1996. The northern half of the study area was primarily cultivated fields (76%), largely a dry-land winter wheat-fallow rotation, but including corn, milo, sunflower, and sorghum. The southern half of the study area was primarily grazed pastures (87%), with a few cropland fields interspersed. Sunflower crop stubble was interspersed throughout the study area and accounted for <1% of the area.

We systematically collected Coyote scats along 10 8-km routes, first in April and again in July. Routes were located along roads and trails, were at least

1.6 km apart, and were distributed throughout the study area. We cleared routes of all scats two weeks prior to each collection. We collected all Coyote scats along each route, and plotted their locations on a map to estimate the minimum number of Coyote family units sampled. We buffered around each scat location with a radius of 4.52 km, which represents the diameter of the average home range size of a Coyote family unit during spring and summer (Gese et al. 1988b). Buffer zones that overlapped were considered to represent the same Coyote family-unit home range.

All scats were stored frozen and later oven-dried for 48 hours at 70°C (Corbett 1989). Dry weights were recorded for all samples. The contents of each scat were washed separately with water through a 36-mesh/cm² sieve and residues were air dried, similar to methods of Greenwood (1981). We identified residues to the lowest taxon possible on the basis of hair, plant material, teeth, feathers and exoskeletal parts. Hair was identified primarily by micro structure (Moore et al. 1974). Seeds and teeth were identified by using reference collections and manuals (Schwartz and Schwartz 1959; Martin and Barkley 1961; Davis 1993). We used frequency of occurrence to present our results (Corbett 1989). Food items found were counted only once as being present or absent. We visually estimated the percentage of scat volume for each food item. Plant material that occurred in trace amounts were excluded from the calculation of overall plant frequency of occurrence because ingestion was likely incidental to consumption of other foods. Occurrence of grass in Coyote scats was not included in the calculation of overall plant frequency of occurrence, because the nutritional value of grass in a Coyote diet is questionable (Fichter et al. 1955).

Results

We found 23 Coyote scats during our systematic searches of the study area. Based on the buffered locations of scats, we believe these represented a

TABLE 1. Frequency of occurrence (n) and percent frequency of occurrence (%) of prey items found in 23 Coyote scats collected in western Kansas during April–July 1996.

	n	%
PLANT ¹	9	39
Commercial sunflower seeds	9	39
MAMMAL	23	100
<i>Sylvilagus</i> spp., cottontail	5	22
<i>Lepus californicus</i> , Black-tailed Jackrabbit	2	9
Unknown Leporidae	10	43
<i>Microtus</i> spp., vole	9	39
<i>Spermophilus</i> spp., ground squirrel	2	9
<i>Cynomys ludovicianus</i> , Black-tailed Prairie Dog	1	4
<i>Geomys bursarius</i> , Plains Pocket Gopher	5	22
<i>Dipodomys ordii</i> , Ord's Kangaroo Rat	5	22
<i>Reithrodontomys</i> spp., harvest mouse	2	9
<i>Peromyscus</i> spp., white-footed mouse	13	57
<i>Onychomys leucogaster</i> , Northern Grasshopper Mouse	3	13
<i>Zapus hudsonius</i> , Western Jumping Mouse	1	4
<i>Mustela frenata</i> , Long-tailed Weasel	1	4
<i>Mephitis mephitis</i> , Striped Skunk	4	17
<i>Odocoileus</i> spp., mule or white-tailed Deer	3	13
<i>Antilocapra americana</i> , Pronghorn	7	30
<i>Bos taurus</i> , Domestic Cattle	4	17
Unknown mammal	11	48
BIRD	2	9
Unknown bird	2	9
INSECT	7	30
Carabidae, ground beetle	3	13
Tenebrionidae, darkling beetle	2	9
Scarabidae, scarab beetle	1	4
Unknown Coleoptera	6	26
Acrididae, short-horned grasshopper	1	4
Unknown Orthoptera	2	9
Unknown insect	2	9

¹The overall frequency of occurrence of plants does not include the grass or other seeds categories. Grass was excluded because its nutritional value in the Coyote diet is questionable (Fichter et al. 1955). The other seeds category was excluded because the seeds occurred in trace amounts and ingestion was likely incidental to consuming other foods (e.g., seed-eating prey item).

minimum of seven individual Coyote family units. The mean scat weight was 12.84 g (SD = 8.92).

Mammals were the most frequently occurring food item in Coyote diets (Table 1). Overall, 10 families and 16 genera of mammals were identified as food items. Commercial sunflower seeds were second in frequency (39%). In 4 of 9 (44%) scats that we found containing commercial sunflower seeds, seed remains constituted $\geq 30\%$ of the volume; with an overall mean of 31%. The broken shells of commercial sunflower seeds occurred in 7 of 18 scats collected in April and 2 of 5 scats collected in July. Eight of the nine scats containing sunflower seeds were found in the northern portion of the study area. Insects occurred frequently in the Coyote diet, representing two orders and four families. Birds occurred infrequently in the scats; bird remains consisted only of small broken feather shafts, and thus no species could be identified.

Discussion

Our finding of mammals as the primary food item of Coyotes in western Kansas is consistent with studies throughout the Great Plains Region (e.g., Gier 1968; Springer and Smith 1981; Gese et al. 1988a; Lewis et al. 1994; Brillhart and Kaufman 1995). Our finding of Leporidae as the most frequently occurring mammalian family in the Coyote diet was similar to that observed in Nebraska (Fichter et al. 1955) and Kansas (Gier 1968). Although Coyotes consume many types of fruits and vegetation (Fichter et al. 1955; Gier 1968; Brillhart and Kaufman 1995), no study has indicated the extensive use of commercial sunflower seeds that we observed. One study reported that sunflower seeds occurred in trace amounts (Brillhart and Kaufman 1994, 1995). We recognize small sample size in this study, yet our finding that commercial sunflower seeds occurred frequently and in high volumes in scats suggests Coyotes may con-

sume relatively large quantities of seeds when available. Moreover, our finding sunflower seeds in July indicated that unharvested sunflower seeds remain available in the environment well into the next growing season. Because scats containing commercial sunflower seeds were found within 4 of 7 Coyote family home ranges along our collection routes, a minimum of four different Coyotes appeared to have used seeds as a food source.

The importance of commercial sunflower seeds in the diet of Coyotes is, at present, unknown, although our observation suggests it may be an important food source in some localities, as it is for other carnivores. Planting of sunflower crops has recently increased, particularly in the northern the Great Plains region (U.S. Department of Agriculture, National Agricultural Statistic Service, Published Estimates Database, www.nass.usdagov:100/ipedb/). Although the efficiency of harvest continues to improve, there is still a considerable amount of seeds left in fields after harvest which are available to wildlife (Hofman and Kucera 1984). Harvest loss can result in 45–55 kg of waste seed per hectare (D. R. Berglund, Department of Plant Sciences, North Dakota State University, Fargo, personal communication), providing an abundant food supply when or where other naturally occurring foods may be scarce.

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Pre-fledged Common Loon, *Gavia immer*, on an Acidic Lake Dies with Food Bolus in Esophagus

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Alvo, Robert, and Douglas Campbell. 2000. Pre-fledged Common Loon, *Gavia immer*, on an acidic lake dies with food bolus in esophagus. *Canadian Field-Naturalist* 114(4): 700–702.

A moribund pre-fledged Common Loon (*Gavia immer*) with a bulge in its throat was collected from acidic Silvester Lake. It died soon afterwards. Dissection of the bird revealed that the bulge was a food bolus containing Yellow Perch (*Perca flavescens*), dragonfly larvae (*Somatochlora cingulata* and *Aeschna* sp.), crayfish (*Cambarus robustus*) and whirligig beetles (*Dineutus* sp.). We suggest this bird may have swallowed a large fish that punctured the esophagus on its way to the proventriculus, causing peristalsis to cease. Food subsequently swallowed could not move beyond the esophagus, thus forming the bolus. The loon may have swallowed the large fish because food of suitable size for a bird of that size was in short supply due to the lake's acidity.

Key Words: Common Loon, *Gavia immer*, food, bolus, acid, lake, Sudbury.

Common Loons (*Gavia immer*) that nest on lakes large enough for only one pair (ca. 5–75 ha) often avoid acidic ones. When they nest on these small lakes and lake pH is less than 4.5, young usually disappear long before they would fledge, probably because they starve to death. However, if lake pH is higher than 4.5, fish and other prey organisms are usually present, and young may fledge. Fledging success increases with lake size because even though the food density is likely lower than on lakes with higher pH, there is a greater area (or volume) of water in which to forage, so the total amount of food available to the loon family occupying the lake may be sufficient for fledging to occur. However, foraging success rates tend to be lower on acidic lakes, presumably because of low food density (Alvo et al. 1988). There is often also a difference in prey given to young; Parker (1988) found that loons raising young on low-pH lakes captured prey with a larger size range than on high-pH lakes. He predicted that on acidic lakes some young loons choke on large prey. Here we report a case of a pre-fledged loon dying, possibly from swallowing a large fish on an acidic lake.

Field Observations

A Common Loon nest with two eggs was found on 22 June 1996 on an island in Silvester Lake (46°50'30"N, 80°38'50"W), a 52-ha lake 48 km north-east of Sudbury, Ontario. Lake pH was 4.9, but four readings from 1988 to 1993 had been 4.4–4.7. On 17 July, a loon pair with two downy chicks were seen near the island. From the chicks' size and the moist egg remains on the nest, the chicks' age was 1–2 days. On 18 September, two young, large and feathered, were seen near the nesting island. No adult was seen during 30 minutes of observation. On 28 September, an adult was foraging for one young

(Y1). The other young (Y2) was 200 m away, but soon joined them. Y1 now had a bulge in its neck (see front cover). Y2 begged and pecked at the adult, which fed both chicks, but the food items could not be identified using a spotting scope, nor could the foraging success rate of the adult be determined. Dive-times averaged more than twice as long (mean = 98.7 sec, S.D. = 25.1, N = 41) as for 46–74 day old chicks in an earlier study on lakes with pH 6.7–8.4 (mean = 42.4 sec, S.D. = 14.3) (Alvo et al. 1988). These longer dive times may have been related to low density of fish in the lake or the large size of available fish (requiring longer pursuit and capture time).

On 29 September, two young were present, but no adults were seen. Both looked the same size, appropriate for their age compared to young on other lakes. Y2 manipulated a fish for 10 minutes, but gave up without swallowing it — the prey was too large (at least 18 cm long).

Y1 remained very close to shore, and as RA approached it, it would dive, but not toward open water, and always resurfacing within 20 m. It remained close to shore, rather than the normal pattern of diving toward open water. It floated against the rocks or gravel, motionless. It was very weak, and was collected by hand. After a seven-hour drive to RA's home, Y1 had trouble holding up its head and drowned in 8 cm of water in the bathtub. Assuming a hatch date of 15 July, the chick died at 77 days, or 11 weeks. Its wing feathers were not fully grown, still in sheaths.

On 13 October, after a complete search of Silvester Lake, Y2 could not be found. It may have died, or fledged and departed.

Dissection Results

Y1 was kept in a freezer until 11 October, when it was taken to the National Wildlife Research Centre



FIGURE 1. Contents of food bolus from pre-fledged Common Loon. *Left*: crayfish; *centre*: dragonfly nymphs (below) whirligig beetle elytra (above) and two round structures (on top); *right*: perch.

in Hull. Its measurements were: weight — 1562 g, total length — 605 mm, wingspan — 995 mm, tarsus — 76 mm, bill length (tip to end of feathers) — 55 mm; it was thus smaller and lighter than 2-3 month old young measured by McIntyre (1975).

The bulge in the neck was a food bolus in the esophagus comprised of: 15 Yellow Perch (*Perca flavescens*) plus 6 other possible ones (the longest, from snout to tail fork was 95 mm, and the only other 3 measurable ones were 73 mm, 56 mm, and 55 mm long); 46 dragonfly larvae (45 *Somatochlora cingulata* (length range: 19–26 mm), and one *Aeschna* sp. at too early an instar to identify); 6 *Cambarus robustus* crayfish; 4 *Dineutus* sp. whirligig beetles (Family: Gyrinidae), at least one *D. nigror*, the other 3 probably the same species, or possibly *D. assimilis* (the 4 measurable elytra (hardened front wings) were all 8 mm long); 2 white round structures, possibly consumed for digestive purposes.

Necropsy Results

Necropsy examination by DC showed that, on gross examination, the only significant abnormality was dilation of the esophagus to a diameter of approximately 4 cm. The mucosal surface of the esophagus was covered in plaques of fibrin. The remainder of the digestive tract was normal in

appearance, apart from small amounts of abnormally dark intestinal content.

No lead was present in the proventriculus or gizzard, and testing of liver and kidney did not detect any evidence of lead. Samples of heart, lung, liver, kidney, adrenal gland, esophagus, proventriculus and gizzard were fixed in 10% formalin and processed routinely for histology. Histologic examination confirmed the presence of extensive plaques of fibrin, mixed with cellular debris and bacteria coating an ulcerated mucosal surface of the esophagus. Examination of muscular layers of the esophagus and myenteric plexus failed to detect any abnormality of structure or inflammation.

Discussion

Esophageal impaction, with the development of a bolus of ingested food pressing against the mucosal lining, may occur in birds under a variety of circumstances. The most common cause is lead intoxication by paralysis of the upper digestive tract from effects of lead on the nerves supplying this tissue, as documented in waterfowl (Locke and Thomas 1996) and loons (Pokras and Chafel 1992). In records of the Canadian Cooperative Wildlife Health Centre, 8 of 19 lead-poisoned loons had evidence of esophageal stasis, usually with a bolus of crayfish at the point of distention.

Other than lead poisoning, a major cause of esophageal impaction due to paralysis is inflammation of the nerves of the myenteric plexus. This rare condition has been reported in Canada Geese (*Branta canadensis*) (Daoust et al. 1991). No evidence of inflammatory change in the nerves of the myenteric plexus of this loon was detected, but subtle changes may have been lost during freezing and thawing of the carcass.

A third possible cause of esophageal impaction is simple obstruction of the esophagus due to ingestion of too large a food item. Because of the highly distensible nature of the esophagus of the loon, simple obstruction seems unlikely.

Obstruction may occur by inflammation of the mucosal lining causing an inhibition of voluntary swallowing movements, which, combined with adherence of food items to the inflamed surface, may develop a mechanical blockage. Inflammation of this sort could result from a penetrating wound, either from the outside in, as from a bullet or the bill of another bird, or a wound originating from within the esophagus from a sharp food item, such as a fish bone or fishing hook. However, there was no evidence of an external penetrating wound, nor a localized point of inflammation surrounding a foreign body. The inflammation was widely disseminated, suggesting a broad swath of mucosal damage, such as could occur with the passage of a large, rough textured food item. The denuded mucosal surface would then attract inflammatory cells, exude fibrin and be colonized by opportunistic bacteria.

We suggest that mucosal damage due to the passage of a larger than normal food item, possibly of an abrasive nature, led to severe, locally extensive inflammation and subsequent development of a complete obstruction of the upper esophagus, resulting in emaciation and eventual death. The food item was more likely to have been a fish than a crayfish because of the observations we made of Y2 catching a fish, attempting to swallow it, then finally giving up, apparently because it was too large. This may be another mechanism by which loons may experience low productivity on acid lakes.

The combined results of Alvo et al. (1988) and Parker (1988) documented chicks starving to death on very acidic lakes, a chick feeding itself whirligig beetles before dying on a very acidic lake (pH 4.2), parents suffering lower foraging success rates on acidic lakes, parents departing from a natal acidic lake to forage for themselves elsewhere, and breeding loons occupying larger lakes to make up for the decrease in food density on acidic lakes. The likelihood of chicks choking on food that is too large apparently increases on acidic lakes, as predicted by Parker (1988), who found that chicks on low pH lakes were fed prey much smaller or much larger than that normally preferred.

In 1993, RA discovered that the two loons nesting on Silvester Lake were the same ones sometimes seen on adjacent Wolf Lake, where a nest was never found during four years of observations. He never saw a pair in both lakes at the same time. An aquatic connection roughly 0.5 m deep exists between the two lakes. In 1993, RA observed two parents with two young dive through the narrows from Wolf Lake to Silvester Lake. The two lakes combined cover 140 ha, an extremely large area for one pair of loons (Alvo 1994) — loons in the study area have raised chicks successfully on lakes as small as 8 ha. Use of both lakes by the same pair suggested that one lake was not enough for them, presumably because of acidity (pH of Wolf Lake: 4.9) and related low food density.

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Evidence of Autumn Breeding in Red Squirrels, *Tamiasciurus hudsonicus*, in Western Montana

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Red Squirrels (*Tamiasciurus hudsonicus*) routinely breed biannually in eastern North America, but normally breed once annually in western North America. However, a postpartum estrus resulting in two breeding seasons per year has been documented within the maritime region of British Columbia. I present two accounts of Red Squirrel behavior suggestive of autumn breeding in Red Squirrels in western Montana, and supporting evidence from the literature suggesting that late-season breeding resulting from a postpartum estrus may occur periodically in Red Squirrels within the Rocky Mountains.

Key Words: Breeding behavior, Montana, Red Squirrel, *Tamiasciurus hudsonicus*.

In the northeastern United States, Red Squirrels (*Tamiasciurus hudsonicus*) commonly produce two litters annually; the first breeding period runs from February through March and the second occurs during June and July (Layne 1954; Hamilton 1939). In western North America, Douglas' Squirrel (*Tamiasciurus douglasii*) breeds twice annually (Smith 1968), but the Red Squirrel breeds in the early spring from the end of February to May (Larsen and Boutin 1994; Kemp and Keith 1970; Swanson 1971; Millar 1970; Smith 1968; Hatt 1943). However, Millar (1970) observed two breeding periods on Vancouver Island, British Columbia in 1966; the result of postpartum estrus exhibited by numerous females in the population. In 1967 he expanded his sampling to include an inland population, but observed only a single breeding period at both locations and suggested that second litters resulted from increased food availability in 1966.

Although Millar's (1970) data indicate that biannual breeding can occur in western populations of Red Squirrels in a maritime climate, it is unclear whether inland populations are also capable of biannual breeding. The limited histological studies conducted within the northern Rocky Mountain States offer no evidence of postpartum estrus or a second, late-season breeding period (Dolbeer 1973; Swanson 1971). I present two observations suggestive of autumn breeding in Red Squirrels in western Montana.

In mid-September 1993, while conducting research in the McDonald Valley, Glacier National Park, I observed Red Squirrels copulating in a low-elevation (ca 1020 m) mature Western Hemlock (*Tsuga heterophylla*) stand. One squirrel chased another around an area approximately 1000 m². After about a minute, the first squirrel paused for a few seconds while standing with its tail against its back as the second squirrel slowly approached mounted and copulated with the first. The two separated and the scene was repeated twice. Each time

the first squirrel awaited the second in the same position. All copulations occurred on the ground and were clearly visible within an open understory. The event lasted 5 to 10 minutes. No other squirrels appeared.

On 4 November 1995, I observed apparent Red Squirrel sexual play on Babcock Mountain in the Rock Creek drainage east of Missoula, Montana. As I stopped to note a Red Squirrel chase, two squirrels appeared on top of a log, paused for a moment, and the second squirrel approached and mounted the first. The chase immediately continued and I watched until the two squirrels disappeared in a large Douglas-fir (*Pseudotsuga menziesii*) tree. The habitat was a dry, mid-elevation (1580 m) Douglas-fir stand on a south-facing slope. Other squirrels vocalized nearby, but I saw none in the immediate vicinity.

The September copulation account is consistent with observations of breeding behavior in Red and Douglas' Squirrels described by Smith (1968) in Washington and with the timing of postpartum breeding of Red Squirrels reported by Millar (1970) on Vancouver Island. Hatt (1943) described a similar copulation event between a pair of Red Squirrels in September in Colorado that is suggestive of late-season breeding along the front range of the Rocky Mountains.

The November observation was likely sexual play as defined by Smith (1968) as I did not observe a definite copulation and the timing would seem too late even for a late-season breeding event. Given that sexual play occurs between recently weaned young males and their mother, or among young squirrels of a litter for about two weeks after weaning (Smith 1968), and that weaning occurs approximately 60 days post parturition (Smith 1968; Nice et al. 1954; after correcting with Lair's [1985] estimate of 33 days for gestation), the estimated time for conception for squirrels exhibiting sexual play in early November would be from mid August to early

September. This timing is consistent with the period associated with postpartum breeding on Vancouver Island (Millar 1970).

Red Squirrel breeding in Idaho (Swanson 1971), Washington (Smith 1968), Colorado (Dolbeer 1973), southern British Columbia (Millar 1970), and Alberta (Rusch and Reeder 1978) occurs from late February to early June and is generally centered around March and April. Therefore, any breeding activity occurring in September likely results from a second breeding period or late postpartum breeding (Millar 1970). The two observations described here combined with the one reported by Hatt (1943) in Colorado, and the histological data presented by Millar (1970) from Vancouver Island suggest that a second breeding season may occur periodically in western North American Red Squirrels as far east as the Rocky Mountain front range. The irregularity of such breeding (see Millar 1970) would make it difficult to obtain conclusive histological data. However, biologists should be aware of the potential for autumn breeding within Red Squirrel populations in order to better document and potentially quantify this phenomenon.

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News and Comment

The Ottawa Field-Naturalists' Club 1999 Awards

The Ottawa Field-Naturalists' Club held its annual Soirée at the Unitarian Church in Ottawa on 14 April 2000. Pictorial coverage by Peter Roberts and reporting by Fenja Brodo for the event has appeared in *Trail & Landscape* 34(3): 87–91 (July–September 2000).

The presidents of the junior club, the Macoun Field Club, Alexander Stone (Juniors), Mark Hickman (Intermediates) and William Godsoe (Seniors) spoke on field trips and speakers of over the last year for their groups. Prizes were presented for natural history exhibits and judges Diane Lepage and Fenja

Brodo awarded First prize to Julian Potvin-Bernal for his display on dragonflies, Second, to Sara Potvin-Bernal for her "Humpbacked Whales" and third, to Alexander Stone for his presentation on Peregrine Falcons.

The OFNC 1999 awards presentations were made. These recognize and encourage contributions towards the goals of the club by individuals or organizations. Stephen Darbyshire read the following citations and the president, Eleonor Zurbrigg made the presentations.

George McGee Service Award — Betty Campbell

The George McGee Service Award is given in recognition of a member who has contributed significantly to the smooth running of the Club over several years. It is a special pleasure this year to recognize Betty Campbell for her lengthy commitment and dedication to the OFNC.

A long-standing member of the OFNC's Education and Publicity Committee, Betty has developed imaginative and eye-catching exhibits for the OFNC's display panels, which she maintains and updates as needed. She transports and frequently attends them at various venues such as the Wildlife Week Festival, Ottawa Duck Club shows, Earth Day festivities, and many others too numerous to mention. Betty is the one primarily responsible for erecting and dismantling the panels, and in general ensuring that they are not lost, are in good repair and are ready for the next event.

Betty is also the OFNC slide and photo librarian, a position she has long held. Over the years the Club has acquired thousands of slides but until Betty took charge little was done to organize or file them. With her usual efficiency she sorted and classified them into a workable and usable system easily accessed by any Club member who wishes to use them for illustrated talks on natural history. Betty has also developed several themed slide shows, such as the one for International Migratory Bird Day at the Fletcher Wildlife Garden (FWG). Betty is also the official photographer for the garden and her excellent photos have been much used both in FWG displays and

framed as gifts given out by the Fletcher Management Committee.

For some years now she has been an invaluable member of the Fletcher Wildlife Garden's Backyard Garden team (known as the Friday Morning Crew). Most Friday mornings from spring through fall, find Betty hard at work doing all the necessary tasks that help the garden thrive. But Betty is more than a hands-on gardener. During planning sessions for the Backyard Garden (BYG) Betty is the one who frequently comes up with the most practical and workable solutions to various problems. Once the solution is found, discussed and approved, Betty without any fanfare implements it. As an example, when it was suggested that each member of the backyard team be responsible for one of the many garden beds, Betty created an excellent database with maps of the garden that enables each person to keep track of the plants in their bed, allows for expansion, and has the added advantage of being very easy to use. This is just one example of the many ways in which Betty's creativity and ideas have contributed so greatly to the FWG.

Like the deep roots of a tree, strong and enduring, Betty's influence is felt throughout the OFNC, where her work brings to the Club visibility, appreciation, credibility and professionalism in the eyes of the general public, potential new members and Club partners. It is with great pleasure therefore, that we give Betty Campbell the George McGee Service Award.

Member of the Year — Claudia Burns

The Fletcher Wildlife Garden (FWG) has become, to the general public, the most visible face of the OFNC. Generating considerable interest in both the project and the club, it has also served in attracting potential new members. This is particularly true of the Backyard Garden (BYG), which acts as the main focus and can be called, with no exaggeration, the FWG's showpiece.

However, a garden such as this doesn't just happen. It takes planning, hard work and someone with a strong vision to provide leadership and inspiration. Starting in 1998 and through 1999, Claudia Burns has done just that. Indeed her genuine dedication to the project has created a high degree of loyalty amongst the Friday morning volunteers, who have worked hard with Claudia to bring life to their shared vision.

Claudia took over as manager of the BYG at a time of great change. Building upon the work of previous managers she brought energy, zeal and a fundamental understanding of what constitutes a successful wildlife-friendly garden. With the volunteer team, she is largely responsible for shaping the garden as it is seen today. The period 1998–1999 was a

key time for the BYG when the hard work and creative and careful planning really paid off. The garden flourished as never before and attracted hundreds of visitors, including the famed photographer Malak who spent a considerable time taking photos of the area.

With the garden taking shape, Claudia turned her energy to helping write and produce a brochure that explains the principles of wildlife gardening. Entitled "Gardening for Wildlife, A Guide to the FWG's Backyard Garden" it contains a wealth of information designed to introduce the public to gardening in a more environmentally responsible manner.

In addition to her work on the BYG, Claudia is a key member of the FWG Management Committee. She works hard ensuring that the project is successful, participates fully in most of the FWG events, and brings her creative vision to bear on just about every aspect of the FWG.

For her hard work, energy, and creativity, and for helping raise the profile of the OFNC through the BYG in such a positive and inspiring manner, we are proud to name Claudia Burns as Member of the Year for 1999.

Conservation Award, non-member — Friends of Petrie Island

The OFNC began to present its Conservation Award for non-members in 1993. This award is the Club's way of recognizing outstanding conservation activities by people or organizations in our local community that are not part of the OFNC.

In June of 1997 a proposal was put to the City of Cumberland for developing passive and active (a marina) recreation areas on Petrie Island at the site of the present sand quarry operation. Recognizing the area as a valuable natural resource, some members of the Cumberland Nature Trail Committee decided that something had to be done to protect the natural portions of the island while developing the adjacent passive recreation area. Thus, in November 1997, the Friends of Petrie Island (FOPI) was formed. This small but very active group has brought an incredible energy and enthusiasm to its chosen task and, in a remarkably short time, has accomplished a huge amount. Two years ago Petrie Island was an unknown swampy area along the Ottawa River frequented mostly by fishermen and the occasional naturalist. Now, thanks to the efforts of FOPI, the area is becoming widely known for its natural values, not only to the general public, but to municipal, regional and provincial governments alike.

The accomplishments of the 12-member board in the past two years have been staggering. Partnerships and cooperation seem to be a hallmark of this organization. Not only have they formed productive

liaisons with the OFNC and the Ottawa Duck Club, but many other organizations have provided assistance. Local youth groups have helped clear garbage and flotsam from the islands and surrounding water. The sand quarry operator assisted with improvement of roadways, parking areas and trails. The City of Cumberland has been convinced to help improve certain features and services around the picnic area and to provide FOPI with regular and special garbage collections and grass cutting. The FOPI have also sought and received operating grants from the City of Cumberland to further their activities.

Politicians and bureaucrats are keenly aware of the FOPI and are constantly being called to task. Every planning meeting and public presentation related to Petrie Island is well attended by FOPI members. They have made their concerns known at City Council, at the regional government planning level and with the Ministry of Natural Resources.

To publicize the plight of the islands, FOPI have been successful in obtaining media coverage for the area. An extensive and professional-looking web site has been established to provide information on the island, including planning issues and nature interpretation. The FOPI have organized regular open houses, hikes and other interpretation activities. They have erected a bulletin board near the parking lot to provide general and interpretive information.

By developing and maintaining a public beach and

picnic area away from sensitive natural habitats, and a short interpretive trail nearby, they have established the value of the island for passive recreation. They have produced pamphlets and other interpretive information along with a map which is sold to help raise money for projects.

The FOPI have organized a monitoring scheme with members on-site to answer questions, monitor usage, and to conduct user surveys. From 1 May to 30 September 1999, 36 volunteers provided 810 hours of monitoring time with the most intensive

occurring in July and August. Their estimate of visitors to the island for the period of May to September is 23,000.

The FOPI have become, through their activities, the effective stewards of the island. They have accomplished much in 2 years, including publicizing the area to local residents, interpretation of the area to visitors, and actively promoting the value and preservation of the island's special natural features. A truly remarkable performance when one considers that their budget expenses for 1999 were only \$1650.

Conservation Award, member — Stan Rosenbaum

The Conservation Award was established to recognize recent outstanding contributions to the cause of conservation in the Ottawa area. As far as the Club is concerned, Stan Rosenbaum has been Mr. Conservation for the last few years.

Stan's primary interests in life have always been outdoor activities such as hiking, skiing, and climbing, and when he retired he was determined to do more to help preserve and protect local areas. A long-time member of the Canadian Parks and Wilderness Society and The Ottawa Field-Naturalists' Club, Stan joined the OFNC's Conservation Committee in 1997 and agreed to stand as Chair in January 1998, a position which he continues to hold. He has injected new energy into the Committee and strengthened it by attracting new members. Stan quickly learnt the ropes of how to deal with conservation issues in the Ottawa District and to connect with the OFNC Council, of which he is a member. He not only keeps on top of

issues, but he is very capable of delegating necessary tasks, including minute writing. He has the Committee communicating by e-mail for rapid turnaround on issues requiring immediate action. He prepares briefs and edits the reports that others write, making useful comments and suggestions, as well as attending many special meetings and open houses on behalf of the Committee. He is able to track older issues, ensuring that progress is made on them, while at the same time researching new problems.

In the last four years the Committee has dealt with the issues of Watt's Creek / Shirley's Bay, Leitrim, South Gloucester, Petrie Island, and Lands for Life, with Stan providing leadership and coordination. His outstanding leadership has revitalized the Conservation Committee to the point where it is once again one of the largest and most active of the OFNC committees, and has had a positive impact on many natural areas that our members enjoy and wish preserved.

Honorary Member — Theodore Mosquin

Ted Mosquin is awarded Honorary membership in the OFNC in recognition of his many active years in the service of the OFNC and for his significant contributions to Canadian natural history and its conservation.

Ted joined the Club in 1963 and became a Council member in 1966. Between the years 1967 and 1972 served as editor of *The Canadian Field-Naturalist*. As editor Ted instigated a number of format changes, including introducing the "News and Comment" section, which have remained to this day. In 1971 he served as Club president. Shortly after joining the Council, Ted put forward a proposal that was immediately recognized as worthwhile. His concept and proposal became *Trail & Landscape*, the vital tool for local Club communications and a wonderful vehicle for local natural history information of all sorts. Once the concept was approved by the Council, it was Ted's job to get the ball rolling, finding an editor, finding a printer and getting all the preliminary struc-

ture in place. Now in its 34th year of publication, the concept of *Trail & Landscape* has proven an incredibly successful and fruitful idea.

Canadian natural history and conservation work has been a passion and life's work for Ted. In 1971 he became the first editor of *Nature Canada* and first President of the Canadian Nature Federation. From President, Ted soon moved to the post of Executive Director in CNF, but he remained editor of *Nature Canada* for six years, until 1977, seeing these important institutions through their initial stages and growing pains.

Ted has been a driving force in many important conservation issues too numerous to mention. What is most remarkable are the ideas, approaches and profound commitment that Ted brought to his conservation work. Innovative and forceful, Ted politicized conservation issues at all levels of government and constantly encouraged other naturalists and biologists to take up the cause. Highlights of his activi-

ties would have to include his seminal role in the origins of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), his role as president of the Canadian Parks and Wilderness Society (CPAWS) for three years, and his organization of the first national conference on Canada's threatened species and habitats.

After completing a Ph.D. in plant cytogenetics and evolution at University of California Los Angeles, Ted returned to Canada to work as a scientist for the federal department of agriculture from 1963 to 1973. Here he pursued diverse research interests in cytotoxicology, pollination biology, autecology and systematics of plants. His scientific studies have also

been innovative and/or pioneering and several of his papers remain much-cited standards in the scientific literature.

Ted's natural history interests have been wide-ranging and far from purely academic. His ideas are often revolutionary and many have withstood the test of time. His legacy is one of innovation and leadership as naturalist, conservationist and scientist. The Ottawa Field-Naturalists' Club is pleased to count Ted Mosquin among its Honorary Members.

Awards Committee
Ottawa Field-Naturalists Club
STEPHEN DARBYSHIRE, Chair

Notices

Biodiversity: Journal of Life on Earth 1(3)

1(3) August 2000 contains: FOCUS: Social forestry in India: An entomological approach [Azariah Babu]; Whale Shark records and conservation status in Venezuela [A. Romero, A. I. Agudo, and C. Salazar] — The dying Mexican tropical dry forests: Finding treasures among the ruins [Alejandro Sanchez-Velez and Rosa Maria Garcia-Nunez] — Principles of the Earth Charter — Forum: It's "double-speak" [R. Warren Bell] — A letter [Kristin Dawkins] and a reply [Joseph S. Papovich] concerning TRIPS — EDITOR'S CORNER [Biosystematics: Key to a billion-year-old web; The beauty of biodiversity] — SPECIES BY SPECIES [Hamilton's Frog, *Liopelma hamiltoni*] — NEWS DIGEST [includes a

call for participation in India's biodiversity action plan, elephants, tigers, and potential help for AIDS patients] — BOOK REVIEWS — ANNOUNCEMENTS.

Biodiversity is published by the Tropical Conservancy, 94 Four Seasons Drive, Ottawa, Ontario K2E 7S1, Canada. The Editor-in-Chief is D. E. McAllister, and the managing editor is Catherine Ripley. Subscription rates for a year (4 issues) are individuals \$25 and institutions \$50. Canadian orders should add 7% GST, foreign orders should be paid in U.S. funds. Special rates are available for developing countries). Additional information on the journal is available at the web site: <http://www.synapse.net/~tropical/publication.htm>.

Froglog: Newsletter of the Declining Amphibian Populations Task Force (41)

Number 41, October 2000, contains: Seed Grant Round 2000 — Amphibian Research and Monitoring Initiative [Stephen Corn, U.S. Geological Survey] — Fish Elimination by Pond Drainage to Preserve a Toad Population in Spain [Alberto Alvarez and Lorenzo Martin] — Establishment of Frog Care Facility in Far North Queensland, Australia [The Cairns Frog Hospital] — Amphibians in Environmental Education in Atlantic Brazil [Germano Woehl Jr. and Elza N. Woehl] — Froglog Shorts — Publications of Interest.

Froglog is the bi-monthly newsletter of the Declining Amphibian Populations Task Force of The

World Conservation Union (IUCN)/Species Survival Commission (SSC) and is supported by The Open University, The World Congress of Herpetology, The Smithsonian Institution, and Harvard University). The newsletter is edited by John W. Wilkinson, Department of Biological Sciences, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk. Funding for *Froglog* is underwritten by the Detroit Zoological Institute, P. O. Box 39, Michigan 48068-0039, USA. *Froglog* can be accessed at <http://www2.open.ac.uk/biology/froglog/>

Marine Turtle Newsletter (90)

Number 90, October 2000, 32 pages, contains: EDITORIAL: Advances with the Inter-American Convention for the Protection and Conservation of Sea Turtles — ARTICLES: Rearing Leatherback Hatchlings Protocols, Growth and Survival — Green Turtle Nesting at Pulau Banyak (Sumatra, Indonesia) — Marine Turtles in Irian Jaya, Indonesia — NOTES: Additional Evidence Supporting a Cleaning Association between Epibiotic Crabs and Sea Turtles: How will the Harvest of Sargassum Seaweed Impact this Relationship? — Report of the Olive Ridley Turtle *Lepidochelys olivacea* in Cuban Waters — MEETING REPORTS — LETTER TO THE EDITORS — ANNOUNCEMENTS — NEWS & LEGAL BRIEFS, RECENT PUBLICATIONS.

The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, United Kingdom; e-mail MTN@swan.ac.uk; Fax +44 1792 295447. Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent to Marine Turtle Newsletter c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; fax + 1 978 582 6279. MTN website is: <<http://www.seaturtle.org/mtn/>>

Errata Canadian Field-Naturalist 114(3)

Alvo, Robert, and Michael J. Oldham. 2000. A review of the status of Canada's amphibian and reptile species: a comparison of three ranking systems. *Canadian Field-Naturalist* 114(3): 520–540. On page 525 (Table 1), the Long-toed Salamander should have “S5” in BC, and a “S3” in Alberta, and S ranks deleted for ON, QC, NB, PEI, NS where the species does not occur. On page 529, on the last line of text, the word “and” should be removed.

On page 532, in the last paragraph in the second column, line 21, the coma after “... extirpation)” should be replaced by a semi-colon. On the following line there should be a coma after “... vs. bear)”. On page 536, 1st full paragraph, line 14, the sentence starting, “The ranks intermediate [sic] ...” should read “The ranks in between would be assigned the numeric values in between ...”

ROBERT ALVO

A Tribute to John Launcelot Cranmer-Byng, 1919–1999

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Godfrey, W. Earl. 2000. A tribute to John Launcelot Cranmer-Byng, 1919–1999. *Canadian Field-Naturalist* 114(4): 710–711.

John L. Cranmer-Byng (Jack to his family and friends) is particularly familiar to readers of this journal for his scholarly book-length biography of ornithologist Percy Taverner, which appeared as a Special Issue of *The Canadian Field-Naturalist*, 1996, 110(1): 1–254. A historian by profession, he had a deep and active concern for the welfare of the natural world, birds in particular.

Jack was born on 18 March 1919 in England in farming country where birds were plentiful. On his ninth birthday, he was given a three-volume illustrated bird book. Thus developed an early mature interest in nature that lasted a lifetime. He majored in history at Cambridge University, graduating with honours in 1940. Even as he wrote his exams, the Second World War was exploding and the student quickly became a military recruit. He enlisted in 1940 as a parachutist in the British Airborne Division, and by 1944 had risen to the rank of Captain. His distinguished military career, in the course of which he was awarded the Military Cross, took him out of civilian life for six years.

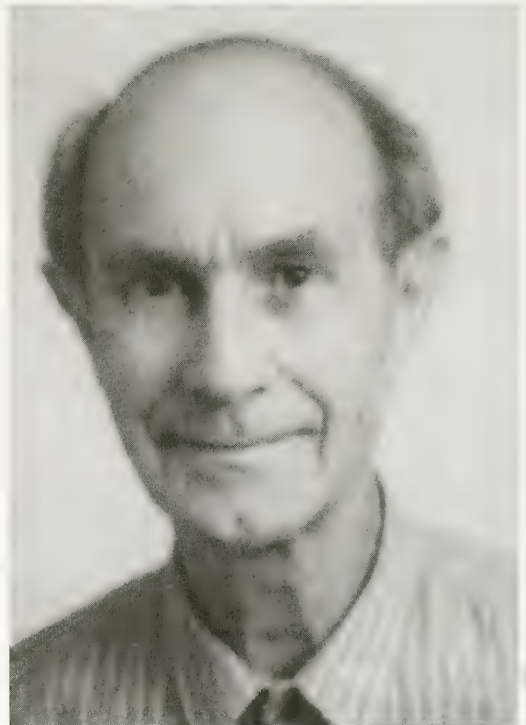
The war over, Jack returned to Cambridge where he took up study of the Chinese language. In 1954, he moved to Singapore to continue his studies of Chinese. It was there he met Margaret, his future wife, who was passing through Singapore en route to take a position in Bangkok. They were married in Singapore in 1955.

A year later they moved to Hong Kong where, as Lecturer at the University of Hong Kong, Jack taught and researched various aspects of Chinese history, published a book and several articles. He retained his interest in birds and was an active member of the Hong Kong Bird Watching Society. It was during this time that the couple's three children were born. In 1964, the family moved to Canada where Jack was appointed Professor of History at the University of Toronto. There he taught and researched the history of Modern China until he retired in 1984 as Professor Emeritus.

By now, Jack's enjoyment of birds had broadened into environmental issues. Saddened by the deterioration or complete loss of so many natural areas, brought about by the growth of Metropolitan Toronto, and foreseeing the need for more citizen participation in improving the situation, he became

actively involved. As member of the University of Toronto's Institute for Environmental Studies, as well as the Toronto Field Naturalists, he ably assisted in assessing the situation and in suggesting remedies. He co-authored an excellent handbook on the subject published by the University of Toronto. In 1978, he received the Conservation Award of the Federation of Ontario Naturalists in recognition of his sustained conservation initiative.

As retirement from the university approached, Jack carefully considered what to choose as a post-retirement project. He became intrigued with the career of ornithologist Percy Taverner. A search revealed that no previous biography of Taverner existed. To Jack, a professional historian, writer, and amateur ornithologist with plenty of time, initiative,



Jack Cranmer-Byng. December 1991

and ability this seemed the ideal project. He soon discovered that an almost overwhelming abundance of resource material existed in the National Museum of Canada and the Royal Ontario Museum. Indeed Jack was soon confronted with the necessity of making a choice of whether to take (A) the easy way out by confining his project to doing a mere chronology of one person's life, or (B) doing it the hard way by including with the Taverner biography all of the wealth of significant information available in the museum files on events, personalities, and achievements that were part of the development of ornithology in Canada in the first half of the twentieth century. Typically, Jack Chose the more difficult way. Consequently, what began as a pastime in the early days of retirement, grew into an enormous task that would demand a decade of meticulous work for completion. But Jack persisted and got the job done. Thus he has given us not only a superb biography of Percy Taverner, but he has, as well, bequeathed to us

a veritable history of the development of ornithology in Canada during the career of Taverner, the central figure. Today students of birds are consulting it increasingly as a rich, extremely well-documented source of historical information on the birds and birdmen of that time. He did it the hard way, the right way, Jack's way. And his enthusiasm for the task did not flag.

Jack passed away peacefully on 6 April 1999, following a stroke. He is survived by his wife, Margaret, who for over forty years actively shared his reverence for the intricacies and beauty of nature, and by their three children, Alison, Colin, and Sheila.

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See also

James, Ross D. 1999. In memoriam: John L. Cranmer-Bying (1919–1999). *Ontario Birds* 17(2): 100–101.

A Tribute to Charles Joseph Guiguet, 1916–1999

YORKE EDWARDS

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Edwards, Yorke. 2000. A tribute to Charles Joseph Guiguet, 1916–1999. *Canadian Field-Naturalist* 114(4): 712–715.

Charles Guiguet — pronounced “gigay” — was a man with amusing sayings. “He went on before” at the age of 84, leaving his wife Muriel and their children now adults: JoAnn, Tricia, Mark and Suzanne. He was born in Shaunavon, Saskatchewan, and attended its primary and secondary schools. His father Laurant Guiguet, and mother Marie, were from France. In 1934 the family moved to Vancouver.

Three leading men in the study of Canada’s birds and mammals launched Charles into the field of museum collecting. In Saskatchewan, James Munro showed him how to prepare specimens for museums. Munro was a federal biologist through the 1930s and 1940s, his territory all provinces west of Ontario, and later reduced to just British Columbia.

In 1936, Canada’s first government mammalogist, Rudolph Anderson in Ottawa’s National Museum, hired Mack Laing who had previously collected specimens for Anderson through three summers while working westward across British Columbia close to the 49th parallel. Laing was known as an outstanding hunter and naturalist. In the field he had shown Anderson that he collected through daylight and wrote his detailed observations by campfires into the night.

Again Anderson hired Laing, this time to study and collect mammals through four summers on British Columbia’s northern coast, this time with an assistant. Early in that year Anderson wrote to Laing:

“Mr. Charles J. Guiguet, 5337 West Boulevard, Vancouver, 20 years old, passed senior matriculation at Shaunavon, Saskatchewan. He has collected for the Shaunavon “Grand Couteau Museum” and makes good mammal and bird skins, and has sent me a number. He needs a job and some encouragement. H. F. Hughes thinks he is a coming naturalist, if he gets half a chance. If you take Guiguet you will have one boy who is willing to work at anything, industrious and full of ambition” (Mackie 1985).

From 1936 to 1939, through four long summers, Laing was Charlie’s leader at collecting mammals on or near British Columbia’s northern coast. In the latter two years they concentrated in the coastal mountains of Tweedsmuir Provincial Park. In their own time important bird species were collected too.

Laing was one of the most knowledgeable and active naturalists in “the Canadian West”. He specialized in both mammals and birds, was known across the country as a frequent writer in outdoor

periodicals, and worked at discovering what species of birds and mammals lived where. It was the time when specimens proved the whereabouts of species in both ornithology and mammalogy. Charles learned Laing’s skills by doing them.

When Laing’s work for the National Museum ended Charles lived year-round in Wells in central British Columbia, where he had been living between some summers with Laing. Playing semi-professional hockey was an attraction and working in gold mines provided income. No doubt hunting in the surrounding wilderness was another lure.

While there he met and married Muriel Waller in 1941.

Leaving Wells, he joined the Royal Canadian Air Force in 1942, trained as a Bomb Aimer, then in 78 Squadron had a bombing series of 23 flights over Germany. In 1944 he was stationed in Italy. The Russian army was pushing German forces back through Poland, and the Poles launched an uprising trying to prevent the leveling of Warsaw. Britain was too distant from Warsaw for Halifax bombers to drop needed equipment and return, so the famed 148 Squadron was stationed in Italy. Flights to Poland then dropped supplies and agents at night. Many failed to return, but “Joe” Guiguet returned from 25 missions.

As graduate students we met at the University of British Columbia in 1948, both with new Bachelor degrees, then in step together toward Master degrees in 1950. Both of us were under the direction of Dr. Ian McTaggart-Cowan. Charles’ thesis was *An Ecological Study of Goose Island with Special Reference to Birds and Mammals*.

He was friendly, energetic, and from boyhood an avid hunter and fisherman of the most successful kinds. Through most of his life he worked and played together in a happy way of combining both. His hunting often began at dawn before work.

We took some courses together. I sat one early morning in a classroom full of tense students about to face an important examination. Just as the exam was to begin, in rushed Charlie, breathless and ready to join the tense crowd. He was fresh from the estuary of the Fraser River, still in hunting clothes and carrying his gun. He had been duck hunting since dawn.

In 1948 he joined the British Columbia Provincial Museum (now the Royal British Columbia Museum) in Victoria as Curator. Through his museum years he



Charles J. Guiguet in Tweedsmuir Provincial Park, near Stuie, British Columbia. 16 September 1938. B.C. Archives, Province of British Columbia, Photo number 6-03674.

worked in summers in wild parts of the province. For 32 years his summers were usually extensions of the earlier summers when he was collecting for the National Museum. His winters were filled with enlarging and caring for the vertebrate collections, writing books, and informing the public through radio, meetings and publications. He was with the museum until retirement in 1980.

In the field his goal was partly biological and partly geographical, which together was — like Laing — discovering where birds and mammals lived. He collected throughout the province, in the south from our almost countless coastal islands and nearby mountains, across the Okanagan and Cariboo plains into the mountainous Kootenay region. Later he was in the north, working from Alberta west through the Cassiar mountains to Alaska.

For years Charlie's makeshift laboratory in Victoria was in a cottage near the museum. Equally makeshift, the vertebrate collections were stored in the attic under the roof of the museum, which was then in the east wing of the main Provincial Government Building. (That wing was finished in 1896 where it housed the museum until 1972.) The attic had no floor, so both storage cabinets and their Curator balanced on the floor joists, a fragile ceiling

below a few inches underfoot and at considerable risk. In 1972 the collections were properly stored near a modern laboratory in a new museum building.

Through later years in the museum he became increasingly interested in the province's hundreds of coastal islands. Many are located near the mainland's shore as well as near Vancouver Island and the two large Queen Charlotte Islands. His island hunts were searches in those small and isolated habitats, looking for nesting sea birds and also hoping to find Deer Mice (*Peromyscus maniculatus*) which he called "the most plastic mammals in the province".

His mammal study was before the time for help from DNA, so he relied on sizes and colours for proposing new subspecies. The museum's book *The Mammals of British Columbia* contained a list of 23 subspecies of *Peromyscus*, most of them isolated on islands. In 1974 he listed in *Syesis*, the museum's annual journal, all mammal species he had found on his island searches.

His home was in Oak Bay, a residential part of greater Victoria. Next to it is ocean water, also called Oak Bay. He found that nine islands in or near the bay appeared to be suitable for Deer Mice, but did not have them. He then took mice from Vancouver Island in the small forest on the property of the



Charles J. Guiguet in the new lab, British Columbia Provincial Museum, Victoria, British Columbia; about 1975.

University of Victoria, and he put mice onto the nine islands. Four islands became populated by mice. He called it his "long term project", for it would probably be a long time before any of the isolated mice showed genetic differences from their Vancouver Island ancestors. He was hoping, I assume, that future studies would show the result of time and isolation causing differences.

He also worked on islands to find nesting sea birds. The magnitude of his searching is shown in *Syesis* for 1971, an example showing that his study of nesting sea birds in Barkley Sound was not easy.

That one inlet has about 150 large islands and reefs plus at least as many small ones.

While at the museum Charlie wrote ten popular books covering the birds in British Columbia, mainly for the province's increasing numbers of neophyte birders. He also co-authored, with his university professor and friend Ian McTaggart-Cowan, a much used book about the province's mammals. Through twenty-two years it had seven printings and two minor revisions. In my time of many travels about the province I saw the museum's many handbooks in use, even in remote homesteads. The series still

grows, some revised, others adding new titles about plants and animals in the province.

In his last years in the museum Charlie was active in planning and collecting material for exhibits to be placed in the new museum building.

Three years before the end of his life he was awarded the Life Time Achievement Award by the Pacific Seabird Group (Carter 1996).

He lived a full life. He helped people. He charmed people and made them laugh. He brightened lives and will live in the memories of many.

Acknowledgements

For details and helpful comments I thank Muriel Guiguet, Mark Guiguet, Suzanne Bancroft, David Nagorsen, Ian McTaggart-Cowan, Atholl Sutherland-Brown, William Rodney, and Michael McNall.

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Owls. 1960. 62 pages;

Chickadees, Thrushes, Kinglets, Pipits, Waxwings and Shrikes. 1964. 66 pages;

Diving Birds and Tube-nosed Swimmers. 1973. 104 pages;

Goatsuckers, Swifts, Hummingbirds and Swallows. 1978. 58 pages;

Sparrows and Finches. 1983. 121 pages.

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Book Reviews

ZOOLOGY

Birder's Field Notebook and Birder's Life List and Master Reference

By Jeffrey Whiting. 1999. Lee Valley Tools Ltd., Ottawa. 316 pp., and 541 pp., illus. \$15.95 and \$39.95.

Lee Valley Tools are justifiably renowned for their superior carpentry and gardening tools. I was, therefore, surprised to be handed two bird books published by this company. Less surprising was the physical quality of the books themselves. Lee Valley has applied the same quality criteria to these books as they do when manufacturing tools. The two volumes look nice and feel nice. While it was easy to identify the publisher it was more difficult discovering the author's name, as it was not immediately apparent.

The first book is a *Birder's Field Notebook* containing just under 300 blank pages for recording sightings. The first 30 plus pages contain a type of condensed birders' 101 course. Various parts of the bird's anatomy from internal skeleton to external feathers are illustrated in sepia plates. A written description accompanies each drawing. For example, tridactyl, didactyl, anisodactyl, and zygodactyl feet are illustrated and explained. Checklist for birding, travelling, and camping are included. There are sections for the addresses of humans and Internet sites.

My problem with the book is I am not sure who is intended to use it. The really avid fanatic will not be interested in much of the first 30 pages and a novice will find it intimidating. However, it is such a beautifully made book and so much nicer than my collection of grubby, dog-eared black notebooks, that I am determined to find a use for it somehow.

The second book is the *Birder's Life list and Master Reference*. Sixty percent of this book is devoted to a checklist of 9702 of the world's birds. Beside each name there is a space to add date and location of each sighting. The remainder of the book

covers a full version of bird biology. Indeed it resemble an adult version of *BirdQuest*, the teaching package put together by the Canadian Nature Federation and Canadian Wildlife Service for use in schools. This includes sections on birdhouses and bird feeding as well as the basics of bird biology. The section on selecting binoculars is the best written, most logical I have ever seen in print. While I believe this will be a handy reference I noted some troubling errors. In the section on plants suitable to attract birds I saw several inaccurate hardiness zones. For example, Saskatoon berry is quoted hardy in Zones 4-6. Saskatoon, renowned for its abundant, juicy berries, is in zone three. In the dimensions of bird houses the entrance hole for bluebirds is given as 1.5 inches. This is normally dropped to 1.25 inches in areas where Starlings are a problem.

Now comes the important question. Who is the book for? The answer in this case is much clearer — the new world birder — that affluent band of people who take annual trips to exotic places to experience new life birds. Surveys tell us that most people start becoming keen around 50 or so years of age. This coincides with the departure of offspring and the availability of more discretionary money. This book would be a beautiful place to keep a world encompassing life list and would make an excellent gift. Somehow, though, I feel I would need to brush up my calligraphy before I write in it. My normal chicken scratch seems out of place in this most handsome book.

ROY JOHN

2193 Emard Crescent, Beacon Hill North, Gloucester, Ontario K1J 6K5, Canada

A Guide to the Birds of Southeast Asia

By Craig Robson. 2000. Princeton University Press, Princeton, New Jersey. 504 pp., illus. U.S. \$59.50.

This guide is a follow up to Ben King's original book which covered 1198 species. This update deals with all the 1251 species known to have occurred in Southeast Asia, an area defined as Thailand, peninsular Malaysia, Singapore, Myanmar (Burma), Laos,

Vietnam, and Cambodia. King's original had some illustrations in colour, but many were in black-and-white. This new book is illustrated in colour, except for the 11 species that are not depicted. However, the illustrations are cramped, averaging about 30 to a page. For example, there are 40 birds illustrated on the gull and jaeger page, plus five heads. There are 43 birds depicted on the woodswallows and starlings

page. While this is not issue for the more distinctive species, it is a problem for those that are difficult to identify. Imagine identifying wren babblers or pipits (the Asian equivalent of ours Ibj's or little brown jobs) on an illustration that will fit in a 1 by 2 cm box! I am sure I would have trouble splitting Lesser from Greater Spotted Eagle using only this guide.

Fourteen artists have contributed to this book. The overall quality of the artwork is high and relatively consistent in format and style. I have found that European or North American artists can sometimes paint the version of a species that occurs in their own backyards rather than the one covered by the book. So I checked the illustrations of Coal Tit and two subspecies of Great Tit (*Parus major ambiguus* and *P. m. nubicolus*) given on Plate 76. Both were accurate.

The text is similar to the King Guide in both style and detail. There is some new and updated information. The biggest difference is that range and status are given more precisely. The author uses terms such as scarce, but as he does not define their meaning this leaves some of the information open to interpretation. However, this is still a valuable and useable contribution. I did have to research a few species as the author used different names. For example, the Mangrove Kingfisher (*Halcyon chloris*) appears as the Collared Kingfisher (*Todiramphus chloris*) and

the Yellow-breasted Green Magpie (*Cissa hypoleuca concolor*) is called the Indochina Green Magpie (*C. h. jini*).

This book is odd in that it starts with miscellaneous information such as a glossary and references, rather than tucking them at the rear; a curiosity but not important. The publishers have changed from King's size of 13 cm x 19 cm x 3 cm to a less pocket-friendly 16 cm x 24 cm x 3 cm. A shorter, fatter book would have been easier to stuff in pockets and backpacks.

It is hard to believe King's work is now a quarter of a century old, and it was time for an updated replacement. This book delivers both an update and advancement. Despite the cramped style of the plates and, to some extent, the text, it is a significant contribution to anyone's ornithological library. It has the increase in species coverage and with all illustrations in colour, it is now the book to use as a field guide in Southeast Asia.

Reference

A Field Guide to the Birds of South-East Asia. By Ben King. 1975. Collins, London.

ROY JOHN

2193 Emard Crescent, Gloucester, Ontario K1J 6K5

New World Blackbirds: The Icterids

By Alvaro Jaramillo and Peter Burke. 1999. Princeton University Press, Princeton, New Jersey. 431 pp., illus U.S. \$49.50.

This latest offering in the Helm-Princeton series on bird groups is entirely North American both in its subjects and authorship. Indeed, the latter has a strongly Canadian flavour, as Jaramillo was raised and educated in Toronto, and Burke is a Canadian bird artist. Their topic is a family that includes many of the most conspicuous and intriguing of New World birds, from our familiar grackles and cowbirds to the tropical oropendolas and caciques.

The book's format will be familiar to readers of previous volumes in this series. It starts with an 11 page overview of the Icteridae, and then covers the 103 species recognized by the authors in a series of individual accounts ranging from 2 to 8 pages in length. There is a comprehensive 30-page bibliography, and indices to both English and scientific names, but no general index. The 39 plates illustrate one to four species per page, each with small range maps and summaries of diagnostic characters on the facing pages.

The authors state that they see the book as a summary of the "natural history of the icterids", neither a field guide nor a handbook on the family, but a general reference, falling somewhere between the two. I think they have succeeded admirably.

The real strength of the book is in the individual species' accounts: the general introductory sections are quite brief, and quite a lot of the space is devoted to a rather general discussion on species limits and nomenclature. Hence anyone looking for a comparative review of the fascinating displays of the icterids, or on the evolution of parasitism, for example, will have to look elsewhere.

The individual accounts are much more comprehensive. The sections on identification and description are particularly thorough, with measurements given for each race. There are many useful pointers on identification that should be of real help in the field. Distribution and geographic variation are also well covered, and the annotated references section at the end of each account should make further reference easy.

Behaviour, nesting, and related matters receive

less detailed treatments, but these are still sufficient to provide good overviews for each species. I had a few problems, however, with some of the material. For example, the statement that "Brewer's Blackbirds need dense shrubs for nesting and is particularly . . ." runs contrary to my own Ontario experience, where the species sometimes uses the rank grasses in roadside ditches. I also thought that the comments about the impacts of cowbird parasitism on Kirtland's Warbler rather understated the issue.

A broader matter is the sloppy editing which pervades the book. A random example is in the Brewer's Blackbird account above, where the reader may have already noted the singular verb. Then the very next sentence lacks any verb. Isolated problems of this type crop up in most books: it's very difficult to catch everything! But here there are many and while these problems are individually minor and I found none that seriously altered the sense of the account, they detract from the otherwise excellent quality of the material.

Turning to the plates, I was very pleased with the

number of plumages illustrated for many of the more common species. For example, there is a full page of Red-winged Blackbird images, plus another half page of 'Bicolored Blackbird', the California races that resemble Tricolored Blackbird, shown on the same plate as the latter. Many of the images are very good, although others are rather "wooden"-looking, and the tiny flight illustrations sometimes look artificial. However, they all do their job, and I enjoyed Burke's little suggestions of habitat in many of the images.

Overall, this is an excellent contribution to this series. With its comprehensive series of plates and descriptive material it should appeal particularly to the birder. Add the good summaries of general natural history and the extensive bibliography, and it will be of value to anyone working in this field.

CLIVE GOODWIN

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Mammals of Madagascar

By Nick Garbutt. 1999. Yale University Press, New Haven and London. 320 pp., illus. U.S. \$37.50.

You will, unfortunately, be hearing of Madagascar more in the coming years. As in many developing nations, pressure for resources is resulting in extensive habitat loss and, as a result, numerous species and ecosystems are endangered. Making it worse though is that there are few places on earth as special to world biodiversity as this island off the eastern coast of Africa. Madagascar supports an unusually high degree of endemism — 90% of the 117 mammal species are only found on this large island, separated from Africa by 400 km of ocean and 120 million years.

This book is a hybrid product, part picture book and call-to-arms for conservation of wildlife, and part scientific treatise on mammal taxonomy, behaviour, and habitat in Madagascar. As such it should be of interest to the scientific community, ecotourists, and concerned conservationists. The author is an established nature photographer and naturalist and, though he does not appear to have formal scientific training, he does a very good job of glean- ing scientific publications on each species. There is an extensive reference section, however, at least for researchers, it would have been helpful to provide the reference in the species accounts themselves. The photography is unsurpassed for a book that presents every species, rare and common, in a region.

Virtually every species, and for primates, both males and females, are shown with high-quality images in natural habitat.

The book begins with an overview of the biogeographic regions on this 590,000 km² island, 4th largest in the world. Besides the distance and time of separation, the uniqueness of the species is due to diversity of habitat; large mountain ranges, spiny savannah, humid forest, and lush jungle can occur in close proximity across the island. Species accounts, which comprise much of the book, are arranged by taxonomic Order, beginning with bats, the only native species found off Madagascar, and ending with bush pig, an introduced species. Marine mammals are not included. I was disappointed also to not find a key for identifying species, strangely absent for this type of book. A large part of the book is reserved for Lemurs, a group of 33 Primate species found only on Madagascar and the group many people associate with the island. The author does an admirable job in describing the special nature of these diverse animals. Lemurs are a relatively primitive form of primate and though their ancestry is debated, their existence and diversity on Madagascar likely is due to the absence of more advanced apes and monkeys. Several large species went extinct in the recent past, apparently at the time of human arrival.

Madagascar is famous for its Lemurs and, as a

result, ecotourism opportunities are increasing. The book summarizes the best places to view mammals with a summary of seasons, access and facilities. Often, the sites exist in the scattered reserves and parks but several Lemur species are habituated and can be seen close to towns. The book ends with chapters on extinct mammals, size of existing reserves, and contacts for organizations trying to pro-

tect the mammals and environment of Madagascar — an obvious appeal for a worthy cause.

G. J. FORBES

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The Smithsonian Book of North American Mammals

Edited by Don E. Wilson and Sue Ruff. 1999. Smithsonian Institution Press (Canadian distributor UBC Press, Vancouver, B.C.) xxv + 745 pp., illus. \$95.

This book includes an account of over 400 species of mammals (except *Homo sapiens*) that live north of the U.S.-Mexican border. There are short, general introductory notes on each order and family. Each species account is a short essay on the animal's characteristics and biology. Supplementary notes include identification and a list of subspecies. Other common names are also given and this is a useful addition as I found some of the prevailing U.S. names are different than those used ordinarily in Canada (e.g., Mountain cottontail instead of Nuttall's cottontail, *Sylvilagus nuttalli*, a rabbit that lives in the prairies). Beside each account is a distribution map of North America from Panama to the Arctic. For those creatures that also occur south of the USA-Mexican border the range is given as far as Panama.

The accounts are well organized and logical. A person arriving on this continent for the first time would get a clear and comprehensive understanding of its mammal inhabitants. The one drawback is that scientific terms are used liberally. For those not familiar there is a glossary, but many of the technical words used are not covered (e.g. hymenolepidid and nonsanguinverous)

This is not a field identification guide. Information for separating individual species is often by such characteristics as dentition or basal hair colour. I found many key field characters were not mentioned. For example the shape of a flying squirrels tail — as it sails overhead — or the belly colour of deer. Photographs, mostly in colour, illustrate nearly all the species discussed. While the majority of these photographs is of good quality and many are exceptionally fine and artistic, few could be used for field identification.

The range maps give the full North American distribution. However, I have problems with the Canadian distribution of many species. Two examples, one from each side of the country will highlight my concerns. In the last few years Moose have started to push north from the north shore of the St. Lawrence into Labrador. They are now approaching the Goose Bay – Churchill Falls corridor and are closing in on traditional caribou territory. The range in this new book is far too extensive to the north and does not go far enough east. In the west, Pronghorn are shown as living in southwestern Manitoba, but absent from most of southern Alberta (the map scale is small so I have taken care to interpret the range as carefully as possible). Recently, I worked four months with a crew surveying wildlife in SW Manitoba and never made or heard of a pronghorn sighting. Last year I led a tour through southern Alberta through the Milk river valley to Waterton and had some fine views of pronghorn. My observations match the range information given in Banfield.¹

This is a very fine book for those wanting a solid but straightforward reference text on mammals. I will certainly consult it when I travel to other parts of North America. For Canadians, Banfield is more accurate and more detailed, even with its somewhat antiquated sections. It would not hurt to have both books.

Reference

¹Banfield, A. W. F. 1974. The Mammals of Canada, National Museums of Canada, University of Toronto Press. Toronto.

ROY JOHN

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Tadpoles: The Biology of Anuran Larvae

Edited by Roy W. McDiarmid and Ronald Altig. 1999. The University of Chicago Press, Chicago and London: xiv + 444 pp., illus. US \$70.

Ten years in the making — according to the editors' amusing preface — this exciting new volume is a compendium of our current understanding and ignorance about the biology of tadpoles. Fourteen authors contribute a dozen chapters devoted to the following topics: introduction and brief chronology of research on tadpoles (chapter 1); advice for research on tadpoles (chapter 2); development, morphology, and anatomy (chapters 3 to 6); endotrophic anurans, physiology, behavior, and ecology (chapters 7 to 10, respectively), evolution and maintenance of the tadpole stage (chapter 11), and familial and generic characterizations of known tadpoles (chapter 12). Each chapter could function as a stand-alone paper, yet they collectively form a cohesive body of information. The editors deserve credit for encouraging the contributors to present their own opinions and interpretations in their respective chapters, regardless of what their fellow contributors may have said elsewhere in the same volume. Too often summary volumes of this sort shy away from anything but the most agreed upon viewpoints — this may be safe, but it results in a rather pedestrian presentation that rarely stimulates the reader's interest. The main body of the book is complemented by numerous figures, followed by a much-appreciated glossary of terms, a reference list totaling a respectable 70 pages, and a trio of indices arranged by author, subject, and taxa.

I was particularly struck by two recurrent themes throughout this volume, the more obvious being the dramatic ways in which metamorphosis from the

tadpole to the adult stage affects virtually every aspect of anuran morphology, behavior, and ecology. This historically has been a fruitful area of research for generations of 'pollywogologists.' The editors' practical "how to" advice for conducting research on tadpoles, coupled with their proposed standardized terminology and descriptive format, promises to promote future investigations and, just as importantly, effective communication among researchers. The second theme evident in this volume concerns the many gaps in our knowledge of tadpoles. To cite three obvious examples: the tadpole stage remains unknown for a variety of anuran species; little is known about the diversity and biology of tadpoles in many tropical regions; and, aside from a few spectacular occurrences, the fossil record of tadpoles is sparse and seemingly uninformative. More problematic is the fact that despite numerous attempts, a robust phylogeny has yet to be presented for frogs. Until a reliable phylogenetic framework based on carefully evaluated larval and adult characters, critical extant and fossil taxa, and a published data matrix are available, interpreting trends among frogs in any meaningful evolutionary context will remain an elusive goal.

I have nothing but praise for *Tadpoles: The Biology of Anuran Larvae*. The accounts are engaging and the presentation is effective. Whether the book is read in an orderly manner or dipped into at random (I confess to a fair bit of the latter), there is much to discover between its covers.

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BOTANY

Atlas of Rare Endemic Vascular Plants of the Arctic

By Stephen S. Talbot, Boris A. Yurtsev, David F. Murray, George W. Argus, Christian Bay, and Arve Elvebakk. 1999. Conservation of Arctic Flora and Fauna (CAFF) Technical Report Number 3. U.S. Fish and Wildlife Service, Anchorage, Alaska, 99503. iv + 73 pages. Free.

This is a wonderful new way to look down on our northland — not just a country at a time but all at once, and in that area north of the treeline discovering that there are plants of very restricted ranges. The authors have done a tremendous job and should be congratulated for their efforts. With the ongoing changes that are taking place in our world's climate they have put a finger on the pulse of 96 taxa which

"are imperiled globally because of their rarity (fewer than 20 occurrences or 3,000 individuals, or few remaining individuals or hectares of habitat), or because of other factors that make them demonstrably vulnerable to extinction throughout their range". These are all endemic taxa and are not taxa that are rare in some countries but frequent in others, although any species which is rare in one country should be of concern to that country.

The text is divided into Background, Methods, and Results. In the Results section there is a summary of statistics which provides a list of the numbers of rare taxa in Russia, United States,

Greenland, Canada, and Norway; a list of 21 families with the number of taxa in each; and numbers of rare vascular endemic taxa of the Arctic in IUCN Red List Threat categories. This is followed by a systematic list for each of the taxa with the additional information:

1. The accepted name of a species, subspecies or variety,
2. Principal synonyms and misapplied names,
3. Plant family,
4. Latitudinal (zonal) geographical subzones,
5. Longitudinal (sectorial) geographic element, floristic subprovince,
6. Ecology,
7. Conservation status of a taxon (IUCN Protected Areas Management Category), and
8. (frequently) additional interesting information.

Following the above is an appendix listing 14 excluded taxa with similar information, a second

appendix providing the latitudes and longitudes of the rare taxa and the countries in which they are found and a third appendix in which distribution maps are provided for each of the 96 taxa, four to a page in alphabetical sequence, with the arctic region outlined and the locations clearly standing out as red dots.

Scattered through the text are maps depicting protected areas, an overall distribution of rare endemic plants of the arctic in relation to protected areas, and a number of absolutely beautiful colour pictures.

Again a tremendous work!

WILLIAM J. CODY

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Trees of the Pacific Northwest

By George A. Petrides. 1998. Backpacker Field Guide Series, Explorer Press (Canadian distributor Fitzhenry and Whiteside, Markham, Ontario). 104 pp., illus. U.S. \$19.95 + shipping.

This is an excellent little book that can be used to quickly identify all the trees that grow wild in Oregon, Washington, Idaho, Montana, British Columbia, Western Alberta, Yukon, and Alaska, either in the field or specimens that were carefully collected and taken home, and "is intended to assist residents and visitors in enjoying the magnificent forests and landscapes of the Pacific Northwest by increasing their ability to identify the trees."

In this work 134 native or naturalized trees are treated. The keys and descriptions are all in easily understood English but scientific names of the

species are included so that easy reference to a flora can be made if necessary. Distributions, habitats, and other interesting comments are also provided and all species descriptions are accompanied by excellent line drawings by the author's daughter, Olivia Petrides. A special key to trees in leafless condition, references, and an index to common and scientific names, together with an order form, complete the work.

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ENVIRONMENT

The Living Planet in Crisis: Biodiversity Science and Policy

Edited by Joel Cracraft and Francesca T. Grifo. 1999. Columbia University Press, New York. xxiv + 311 pp., illus. Cloth U.S. \$60; paper U.S. \$28.50.

The Living Planet in Crisis was the title of a conference held at the American Museum of Natural History in 1995. The present volume draws together papers presented at the conference. The book is divided into four parts. Part 1, Science of Diversity and Extinction, presents four papers on biodiversity and species loss. Part 2, Consequence of Biodiversity Loss: Science and

Society, adds the human dimension, through five papers focusing on human population, agricultural, and potential effects of biodiversity loss on disease. Part 3, Biodiversity Science and Policy Formulation, features three papers on applying biological knowledge to political systems. The book concludes with Part 4, What Needs to be Done. Two papers tackle the problems of scientists working with policy makers and the fundamental shift that must occur among humans if we are to conserve much of the world's biodiversity.

Most of the general ideas in this book are not new. The papers re-state the problems facing the living planet: too many humans devouring more and more of the Earth's resources. The concluding chapter of the book repeats Herman Daly's analogy that we are using the world as if it were a business in the process of liquidation. Therein lies one of the problems with the book, it is often just repeating what has been said before. On the other hand, in a world inundated with advertising incessantly urging everyone to consume more and more (over \$US 360 billion was spent on advertising in 1995; page 281) there is great need to encourage more ecologically sound points of view.

If most of the basic themes are familiar the details are almost always fascinating, if not depressing: worldwide over \$US 25 billion dollars is spent each year on pesticides (page 231). Collectively, governments annually spend approximately \$US 1 trillion on environmentally destructive activities (page 281). The US has lost an average of 24 hectares of wetland every single hour over the past 200 years (page 65). Roughly one-third of protected areas in developing countries

are being overtaken by agricultural encroachment (page 237). One last example to illustrate our profound lack of knowledge about the species we share this planet with: at the current rate at which new species of spiders are being discovered it will take over 250 years to identify all the arachnids (page 47).

It is easy to find a few obvious faults with the book. Despite its global theme, there is a clear United States bias to the writing: all dollar values are presumed to be in US currency and there is frequent reference to "the nation." And genetically modified foods and the surrounding controversy are conspicuously absent from the book. This is particularly surprising given the fact that an entire chapter is dedicated to agriculture. Nonetheless, overall this book maintains a high standard, with most of the papers containing thoughtful material. One can only hope the book's message will be heard by those other than the converted.

DAVID SEBURN

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Requiem for Nature

By John Terborgh. 1999. Island Press, Washington. xii+234 pp. U.S. \$24.95.

Terborgh, who divides his time between Duke University and field research in Peru, is well known for his studies on tropical avian diversity. Island Press is well known for their excellent environmental books. Their collaboration has resulted in an outstanding work. He begins by lamenting the loss of his childhood habitat, with which most readers of this journal over 35 will resonate, and then generalizes to the global onslaught on nature. Terborgh particularly focusses on Peru's Apurimac valley in which he has long worked and which epitomizes how tropical wilderness is succumbing to logging, agriculture, and ruination. The overall context of this loss in terms of governments in turmoil, the drug trade, industrial and military activity, and the continuing explosion of human populations is well described. He argues convincingly that the issue is the extinction of species and the disruption of their interactions. Terborgh demonstrates the need for secure and large parks, especially for megafauna, and the difficult issues raised by indigenous peoples. The book is deftly laced with pertinent data on loss of biodiversity from all ecosystems, tropical and elsewhere. The litany of destruction is long and sickening. The two graphs (pages 61 and 123) depicting the failure to create protected tropical areas and the disappearance of rain forest globally really bring home the message.

Turning from biological to political matters, Ter-

borgh considers what is to be done. His analysis includes many important elements: the distinction of protection and preservation, the mismatch of centres of endemism with park locations, and critical aspects of island biogeography. He regretfully points out the ineffectiveness of many measures including bio-prospecting, ecotourism, non-timber alternatives for forests, and the Global Environment Facility. Terborgh correctly concludes that "sustainable development" is a mirage and that "integrated conservation and development projects" are "wishful thinking" (page 165). This no-nonsense analysis will alarm many entrenched interests but is spot on. He provides a good rationale for governmental ownership of land and accompanying necessary enforcement, and for park trusts ensuring long-term security. Terborgh takes a hard look at what regions may be saved, with unhappy results. Most importantly, he makes clear how governmental policy must face the environmental challenge, and calls for an innovative internationalization of nature protection with features such as a Nature Corps. Terborgh has provided a very real service in bringing together his experience and evaluation of tropical conservation in this volume. The book accurately offers a dismal prospect but is essential reading.

PATRICK COLGAN

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NEW TITLES

Zoology

Amphibians and reptiles of Madagascar and the Mascarene, Seychelles, and Comoro Islands. 2000. By F. W. Henkel and W. Schmidt. Kreiger Publishing, Melbourne, Florida. 336 pp., illus. U.S. \$64.50.

Ants at work: how an insect society is organized. 1999. By D. Gordon. Free Press, New York. x + 182 pp., illus. U.S. \$25.

†**Assessment of bird populations in the Rasmussen Lowlands, Nunavut.** 2000. By V. H. Johnston, C. L. Gatto-Trevor, and S. T. Pepper. Canadian Wildlife Service, Ottawa. 56 pp., illus.

†**Birds of Africa from seabirds to seedeaters.** 1999. By C. and T. Stuart. MIT Press, Cambridge, Massachusetts. 176 pp., illus.

Birds of the world: a checklist. 2000. By J. Clements. 5th edition. Ibis Publishing, Vista, California. 848 pp. U.S. \$39.95.

Bugs: insects, spiders, centipedes, millipedes, and other closely related arthropods. 1999. By F. Lowenstein and S. Lechner. Black Dog and Leventhal, New York. 112 pp., illus. U.S. \$24.95.

†**The California condor: a saga of natural history and conservation.** 2000. By N. Snyder and H. Snyder. Academic Press, San Diego. xxi + 410 pp., illus. U.S. \$24.50.

†**The Canadian Rockies guide to wildlife watching.** 2000. By M. Kerr. Fitzhenry and Whiteside, Markham, Ontario. xi + 243 pp., illus. \$26.95.

†**Ecuador and its Galapagos Islands: the traveller's wildlife guide.** 1999. By D. L. Pearson and L. Beletsky. Academic Press, San Diego. xiii + 485 pp., illus. U.S. \$ 27.95.

†**The encyclopedia of sharks.** 1999. By S. and J. Parker. Firefly, Willowdale, Ontario. 192 pp., illus.

***A field guide to the birds of China.** 2000. By J. MacKinnon and K. Phillips. Oxford University Press, Don Mills, Ontario.

***A field guide to birds of the Indian Subcontinent.** 2000. By K. Kazmierczak. Yale University Press, New Haven. 352 pp., illus. + map. U.S. \$32.50.

***A guide to the birds of Peru.** 2000. By J. Clements. Ibis Publishing, Vista, California. 320 pp., illus. Cloth cU.S. \$68; paper cU.S. \$48.

***The nature of frogs: amphibians with attitude.** 2000. By H. Parsons. Greystone Press, Vancouver. 112 pp., illus. Cloth \$34.95; paper \$24.95.

†**The nature of great apes: our next of kin.** 2000. By M. A. Gilders. Greystone Books, Vancouver. 112 pp., illus. Cloth \$34.95; paper \$24.95.

†**North American important bird areas: a directory of 150 key conservations sites.** 1999. North American Com-

mission for Environmental Cooperation, Montreal. 359 pp., illus. + maps. Available as free PDF download from <http://www.cec.org>.

Salmon nation: people and fish at the edge. 2000. Edited by E. C. Wolf and S. Zuckerman. Greystone Books, Vancouver. 80 pp., illus. \$14.95.

†**Stopover ecology of nearctic -neotropical land bird migrants: habitat relations and conservation implications.** 2000. Edited by F. R. Moore. Cooper Ornithological Society, Camarillo, California. 133pp., illus. U.S. \$18.

***Trogans and quetzals of the world.** 2000. By P. Johnsgard. Smithsonian Institution Press, Washington. xii + 223 pp., illus. + 40 plates. U.S. \$49.95.

†**Wisconsin Fishes 2000: status and distribution.** 2000. By J. Lyons, P. A. Cochran, and D. Fago. University of Wisconsin Sea Grant Program, Madison. viii + 87 pp., illus.

Botany

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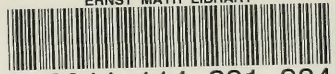
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